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Physical, Chemical and Biological Conditions of the Sagavanirktok River and Nearby Control Streams, Shaviovik and Canning Rivers

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Macrobenthic community samples collected from streams were dominated by Plecoptera, Ephemeroptera, and Diptera, although Annelida, Arcari, and other groups were also present. Within the Diptera, Chironomidae was usually numerically dominant although in some areas, Simuliidae, Ceratopogonidae, Tipulidae, and Tabanidae were important. Lake habitat supported Mollusca, Copepoda, Anostraca, Cladocera, Amphipoda, and Trichoptera. Piscifauna included the arctic grayling, arctic char, lake trout, pike, slimy sculpin, nine-spine stickleback, ling cod, and round whitefish. Total and fecal coliform bacteria values in the stream waters were low. Ranges and patterns of 23 chemical and physical parameters in the aquatic environment were discussed. Measurements of specific cations and anions included dissolved oxygen, phosphorus, silica, sodium, potassium, calcium, magnesium, iron, chloride and nitrogen forms. Collective parameters such as specific conductance, alkalinity, total hardness, pH, total organic carbon and fixed suspended solids were also measured.

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by

Eldor W. Schallock
Ernst W. Mueller

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SECTION I

SUMMARY

RIVER MACROBENTHIC COMMUNITY

Total numbers and diversity of macrobenthic organisms changed with respect to station location on the Sagavanirktok (Sag) River. Total numbers at the mouth increased to about five times the headwaters. Occasionally, large numbers of Chironomidae in localized areas may cause an anomaly in the trend shown by total numbers, but this was usually a single sample found at a single station and, as a result is regarded as atypical.

Total numbers and total diversity found in the macrobenthic community also changed with respect to the time of year the samples were collected. Larger numbers of organisms were generally found at any station in June than at the respective station in August. Generic diversity consistently increased from the Coastal Plain Province to the Mountain Province by a factor of approximately two. Also, the generic diversity found in August is approximately twice the generic diversity found in June.

Three families of Plecoptera, Nemouridae Perlodidae, and Chloroperlidae, were harbored in the Sagavanirktok, and Canning Rivers and in most other stream systems. The exceptions were the Shaviovik River and the Atigun River where Chloroperlidae was not collected. Perlodiadae and Nemouridae were widely distributed during June and August although members of these families appeared less abundant in the Coastal Plain areas than in the Mountain or Foothill provinces. Other exceptions were Perlodidae which was not collected from the Shaviovik River during June and Chloroperlidae which was not found in any of the rivers during the August sample period. Four families of Ephemeroptera, Heptagenidae, Baetidae, Ephemerellidae and Siphlonuridae were harbored in the study streams but not all families were found in all the streams. Lupine and Ivishak Rivers harbored all four families; Sagavanirktok and Ribdon Rivers contained Baetidae, Heptagenidae and Siphlonuridae; Shaviovik also contained three families but Ephemerellidae replaced Siphlonuridae; and Atigun and Canning Rivers harbored only Baetidae and Heptagenidae. Heptagenidae was the most widely distributed and generally the most abundant family as it was found in all rivers during June and August with the exception of the August sample from Atigun River. Baetidae was found in all streams during August but during June it was virtually absent from the three longest rivers, the Sagavanirktok, Canning and Ivishak. Distribution of Siphlonuridae decreased from June to August while the distribution of Ephemerellidae did not appear to change during the same interval. Ephemeroptera was generally less abundant in the coastal plain areas than in the more southern areas.

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Trichoptera was represented by two famlies, Brachycentridae and Limnephilidae, both of which were sporadically distributed in both time and space. During June, Brachycentridae was not present and Limnephilidae was found only in Atigun River and at station S-200 on the Sag River mainstem. During August, both Brachycentridae and Limnephilidae were sporadically distributed along the entire mainstem or the Sag River. During the same interval, of all the Sagavanirktok tributaries, only the Ivishak River harbored caddisflies and then only Limnephilidae. Brachycentridae was the only family found in Canning River. No Trichoptera was collected from the Shaviovik River.

Four families and one suborder of Diptera were widely distributed in the study area. Chironomidae, Tipulidae, Simuliidae, and Ceratopogonidae were collected from all streams although not at all stations during both sample intervals. Chironomidae was widely distributed and was found at virtually all stations in June and August. Both Tipulidae and Ceratopogonidae were discontinuously distributed in most streams although both were more widely distributed in the Sag mainstem and its tributaries during August. Suborder Brachycera was sporadically found in most streams but was completely absent from the Canning River. Most Diptera, particularly Ceratopogonidae, revealed decreased distribution from June to August in both the Shaviovik and Canning Rivers. However, Simuliidae remained about the same or showed wider distribution in August than in June.

LAKE MACROBENTHIC COMMUNITY

The macrobenthic community of lakes share some of the same higher taxonomic categories with stream macrobenthic communities, but the relative importance of these groups may be drastically different. For example, Plecoptera and Ephemeroptera are important to stream communities from both the diversity and numerical point of view. In the lake community, both Plecoptera and Ephemeroptera were collected but were much less important from both aspects. Trichoptera was another example where the lake systems differed from river systems, i.e., Trichoptera was often numerically dominant in lake communities but was not usually important in streams and sometimes was not collected.

Plecoptera was represented in lake macrobenthos by Nemouridae and Perlodidae. Nemouridae was the most abundant family although relatively rare, and was found in both Galbraith Lake and Nora Fed Lakes. Perlodidae was occasionally found only in Galbraith Lake.

Ephemeroptera was even more sparse than Plecoptera. One family, Baetidae, was found only in Galbraith and only during June.

Trichoptera exhibited more diversity in lakes than in streams. Three families, Limnephilidae, Brachycentridae, and a new family, Rhyacophilidae were found. Galbraith harbored Limnephilidae during June and Brachycentridae during August. All three families were found in Nora Fed Lakes but not all in the same lake. During June, Limnephilidae and Rhyacophilidae were collected from Nora Fed No. 1, and Limnephilidae and Brachycentridae were found in Nora Fed No. 2. Only Limnephilidae frequented both Nora Fed Lakes during August.

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Four families of Diptera consisting of Chironomidae, Tipulidae, Simuliidae, and Ceratopogonidae were collected from lakes. Galbraith contained all four families in June but only Chironomidae and Tipulidae in August. Nora Fed Lakes harbored three families during June (Simuliidae were absent) and Tipulidae was found only in Nora Fed No. 1. During August, only Chironomidae was collected from Nora Fed Lakes.

Amphipoda were abundant in both Nora Fed Lakes but were not found in Galbraith Lake. Coleoptera were collected from all three lakes and were generally more abundant than in rivers. Both Amphipoda and Coleoptera were absent in August samples.

The number of macrobenthic taxons from Galbraith Lake are compared to those from Nora Fed Lakes to determine relative diversity. The former macrobenthic community was more diverse than the communities of Nora Fed Lakes although significantly less diverse than those of the streams located in the same area.

PISCIFAUNA

Seven species of fish were collected in the Sag River basin. Four of the species, grayling, arctic char, lake trout and pike, are considered desirable sport fish as well as being good eating. The sculpin and stickleback are not directly significant to man but may play an indirect role as prey fish for the larger carnivorous fish, as a predator on eggs or young-of-the-year or they may also compete with sport fish young for particular size and type food items. Whitefish are not heavily utilized for food but may be important as predators or eggs or competitors for food items.

The clear waters of the streams and the tendency for fish to congregate in specific areas makes the grayling and arctic char vulnerable to angling pressure. Some difficulty can be experienced in finding the fish but once this is overcome, the probability of angler success is high. Consequently, these populations of fish could easily by over-harvested.

Angler interviews and collections of grayling and char indicate that a large percentage of the grayling that are caught are 30 cm (12 in.) or larger and that mostly adult char are caught. This suggests that the population is an accumulation of several years of reproduction and that the population has not been recently harvested. The high percentage of large fish, while creating a temporary angling utopia, carries a warning that heavy exploitation of these stocks will result in a rapid diminishing of the breeding segment of the population thereby reducing the reproductive potential.

Few young-of-the-year of 1+ aged grayling or char were observed. Although the number of fish that was observed was limited, ample effort was made to observe this segment of the grayling and char populations. Pipeline monitoring teams surveying the river system observed small numbers of young fish when compared to other rivers. If this population characteristic is true, small numbers of fish will be added to each population each year to replace those fish lost by natural mortality and angler exploitation. Another possibility exists; that is the young-of-the-year utilize specific tributaries or reaches of tributaries as rearing or overwintering areas. These particular streams then are extremely valuable to the fishery and must be protected.

Adult grayling and char tend to collect in specific locations at spawning time. This behavior makes the spawning populations of both species vulnerable to anglers and to the effects of pollution which could be devastating even though limited to a small area or small percentage of the total stream system if the area affected harbors the spawning pouplation, the developing ova, or young-of-the-year.

CHEMICAL-PHYSICAL PARAMETERS

Physical and chemical characteristics that were measured included temperature, discharge, nutrient chemistry, dissolved oxygen, total metals and nine other miscellaneous analyses.

Seasonal temperature generally decreases when proceeding north. This phenomenon is caused by low angle of solar radiation, number of cloudy days and influence of the Arctic Ocean.

Discharge in the Sagavanirktok River reaches the seasonal high during spring breakup which usually occurs in June. Low seasonal discharge occurs during the winter. Some controversy exists as to whether the discharge is difficult to find under ice and snow cover or whether discharge actually ceases. Concentrations of nitrogen and phosphorus are low and similar to the concentrations found in interior streams. Silica may be limiting to diatom production since ranges as high as 2.0-3.0 mg/l were recorded in North Slope rivers, while concentrations of silica ranged to about 20 mg/l in Interior Alaska. Dissolved oxygen concentrations approached saturation during the summer but were severely depressed during winter (1.1 mg/l). Although sampling during the winter was limited, the observed data suggest that the winter D.O. pattern in arctic rivers was similar to those found in interior Alaskan rivers.

Iron and manganse concentrations were generally below the U.S. Public Health Service standards set on water supplies for human consumption. Concentrations as high as 295.0 mg/l calcium were recorded from the Sagavanirktok River in April, although the summer high was 39.0 mg/l, which is similar to interior Alaska values. Magnesium concentrations ranged from 3.0 mg/l in June to 45.0 mg/l in April. Due to sedimentary substrate of metamorphic origin, concentrations of sodium and potassium were low, ranging from 0.32 mg/l sodium and 0.13 mg/l potassium during summer to 90 mg/l sodium and 4.97 mg/l potassium during winter.

Chemical analyses illustrate differences between summer and winter. pH is basic at all stations, ranging from 7.60 to 8.22 in summer, and 7.25 to 8.55 in April. Closely related alkalinity concentrations ranged from a summer high of 36.2 to a winter high of 875.

Chloride was expected to increase near the Arctic Ocean; the highest values, 233 mg/l were recorded from stations nearest the ocean. Other stations dropped as low as 0.3 mg/l. Hardness is a measure of principally calcium and magnesium. As a result, hardness increased from summer low of 40.0 mg/l to a winter high of 952.0. Conductivity similarly increased from 85 umhos to 1700 umhos.

In general, the water of the Sagavanirktok River is of high quality during the summer with occasional periods of high turbidity during high runoff. Winter surface discharge measurements, although limited, along with communications with industry personnel, reveal a potential problem that the water resources are limited during winter.

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SECTION II

MANAGEMENT IMPLICATIONS

Problems in management of water resources in the Alaskan Arctic can be related to specific features of the arctic environment and to characteristics of the aquatic system. A summary of some pertinent factors of the arctic environment are presented in the introduction.

Among the features of the Arctic that cause management problems is the vastly diminished surface discharge of arctic rivers during winter. During the dominant cold season, the volume of water discharged is a small fraction of the total annual volume. In some reaches of some streams, the movement of water may cease or may be restricted to the thaw bulb within the alluvium. Record of excessive industrial use of this limited discharge in the Sagavanirktok River has been made by Furniss (1975). He relates that some "water holes" utilized by pump trucks have been pumped until water is no longer available to these techniques. When this happens, holes are drilled through the ice in other reaches of the river and the process is repeated. In some instances, water has been transported as far as 80 km (50 mi.).

Furniss (1975) reports that juvenile fish have been pumped into the water trucks that have been transporting water along the Sag River and in some instances the fish survive the hazards of passing through the pump system but in other cases, the fish have been chopped into pieces.

Additional problems were forecast in a study by Schallock and Lotspeich (1974) who revealed that concentrations of dissolved oxygen (D.O.) may be extremely depressed in Alaskan rivers during the winter. Furthermore, the pattern of severely depressed D.O. continued to decline as sampling proceeded downstream. Limited data from the Colville and Sag Rivers documented low D.O. in these drainages and strongly suggest that the D.O. conditions are critical for any effluent or substance that adds oxygen demand, either biological or chemical, to the stream, thereby removing essential oxygen from an already stressed system.

In addition to discharge and dissolved oxygen, other water quality parameters may be abnormal during winter. High values of total alkalinity and specific conductance reveal that certain dissolved cations and anions exceed the concentrations observed during summer and also need treatment to meet State of Alaska water quality requirements to be suitable as potable water. Dissolved constituents such as calcium, magnesium, silica, and nitrates have been known to naturally exceed the State requirements.

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Gravel mining in the Sag River drainage may also be a problem. Gravel is only readily available in the thaw bulb of the Sag River and its tributaries. Although gravel is also present in the permafrost areas, it is too expensive to break free from the frozen substrate and therefore considered unattainable at this time. These features combined with the gross underestimation of the amounts of gravel needed to construct the network of roads, pads, and other insulating and supporting structures for the Trans-Alaska pipeline is causing some concern about the impact of the endeavor in the Sag River system. Initial estimates of gravel requirements for the entire pipeline ranged as low as 4.6 million cubic meters (6 million cu. yds.) However, the last calculations of the amount of gravel used to August 1975 totaled approxmately 161 million cubic meters (210 million cu. yds.). Most of the material that was used on the North Slope (15.2 million cubic meters--20 million cu. yds.) came from the thawed ground located in the flood plain of the Sag River.

At this time, it is impossible to predict the impact of these gravel removal activities on the Sag River. However, biologists and hydrologists share the concern that, while the majority of the material has been removed from the flood plain and not the channel through which water is actively flowing on the surface, the large volumes of gravel removed may cause hydrologic instability that may require years to reassume a state of equilibrium and thus cause effects that last much longer than the actual gravel mining operations.

Aquatic communities may be affected by many of man's endeavors that directly or secondarily alter various parameters of the aquatic ecosystem. It is beyond the scope of this paper to present the array of causes or effects that can alter the structure of an aquatic community. However, some of the more apparent causes that may affect the arctic aquatic community are presented.

Road building, pad construction, pipeline placement, sewage effluent, wasted drilling products, and domestic and industrial water, if improperly managed, may have serious adverse impcts on one or more elements of the complex interrelated aquatic system. Hynes (170) states some of the many ways this can happen. Diverson of the water from a channel results in dessication and disruption of life patterns or in death for the organisms inhabiting the affected reach. He further states that temperature changes may result and that the pattern of change, rather than the absolute temperature change, can be extremely important. Aquatic systems may also be affected by the addition of siltaceous material in an untimely manner and/or in abnormal amounts. These are some of the effects:

(1) reduction of light penetration necessary for photosynthetic processes by periphytic diatoms

(2) filling of interstitial spaces

(3) covering of food items

(4) flora and fauna abrasion

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The effects of a particular substance depends upon the timing of the addition, the characteristics of the receiving water, and the nature of the pollutant. When added to lakes, the substance may have a prolonged and localized effect. However, streams receiving a problem substance transport the material downstream, thereby affecting any biota that are inhabiting the specific reach of the stream. The distance the effect is noticeable depends upon numerous factors including volume, type, toxicity of the substance, sensitivity to the indigenous organisms, and the physical and chemical processes that hasten or retard the disappearance of the problem substance.

Naturally occurring winter low water discharge, severely depressed dissolved oxygen concentrations and high dissolved constitutents, combined with large volumes of gravel removal, heavy utilization of available water, and addition of substances via effluent or accidental spills, all combine to forecast an uncertain long-range future for the mineral, water and biological resources of the Sag River.

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SECTION III

INTRODUCTION

RATIONALE FOR STUDY

Discovery of huge oil fields in the Arctic, the national energy crisis, and the Middle East conflict have focused national and international attention on Alaska's Arctic North Slope. Private geophysical exploration crews and a small number of government-sponsored oil drilling rigs have been prospecting on the North Slope for the past 25 years but the effort was small until the 1968 announcement of the discovery well at Prudhoe Bay by Atlantic Richfield Company when the effort increased exponentially. The wide ranging exploration of geophysical crews and followup development efforts stimulated concern about the effects of the oil industry on the arctic environment.

In the past this environment has been considered relatively unaffected by man's activities although it is extremely fragile as there are only a small number of pathways for energy transfer to higher trophic levels in the ecosystem. Prior to recent increased activity, man restricted himself to travel between villages along the coastal area with only occasional limited penetration into the North Slope interior on hunting forays. Native villages were built along the coast because of marine food sources. Point Barrow, the largest village on the North Slope, is a blending of about 2,100 Eskimos and Caucasians. The only other sizeable gathering of people along the Beaufort Sea was Barter Island (123). However, within the past 5 years, more developments have sprung up at Prudhoe Bay, Sagwon, Galbraith Lake, and Happy Valley in the Sagavanirktok River basin alone. In addition, isolated drilling sites and wide ranging geophysical exploration may be found anywhere, as witnessed by abandoned gravel pads, modern day middens, and a telltake network of mans' recent treks across the tundra.

Man has encountered the distinctive environmental features of the Arctic while living and working on the North Slope. In dealing with these features, it soon became clear that utilizing techniques that were workable in more temperate climates created problems that were often more severe than effectively dealing with the original arctic characteristic. These characteristics include, but are not restricted to the following disciplines: North Slope climate, geology, morphology, topography, pedology, hydrology and limnology, all of which interact with each other. Some of these features may be found elsewhere but this combination of features and the seasonal periodicity of the arctic environment result in characteristics that are not reproducible in other nonarctic areas. The dominance and significance of cold climate environmental features are not widely known. As a result, a summary of some dominant features are presented for general background information.

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LOCATION

The North Slope has been defined as the part of Alaska that drains into the Arctic Ocean, excluding the arc south of Point Hope (Orth, 1970). The Alaskan North Slope extends west from approximately 141°W longitude at the Canadian border to about 167°W longitude near Point Hope and north from approximatly 68°N latitude in the Brooks Range to about 71°N latitude near Point Barrow.

Wahrhaftig (1965) has divided the North Slope into three physiographic provinces: Arctic Coastal Plain covering 70,900 square km; Arctic Foothills encompassing 95,500 square km; and the Arctic Mountain Province of which 40,500 square km (approximately 30 percent of the total 135,200 square km) are located on the North Slope.

WEATHER AND CLIMATE

The Arctic Climatic Zone of Alaska is described by Watson (1969) as having low temperature variations, extremely light precipitation, strong and common winds, mean annual temperatures ranging from 10 to 20°F with marine environment influencing the summer temperatures but not the winter temperatures. This climate can best be described as harsh in comparson to the climates of other areas.

Temperature is one of the dominant features of the Arctic. Nordenskjold (1928) states that the highest mean monthly temperature at Point Barrow is 3.3°C (37.4°F) in July and the lowest is -28.9°C (-20.2°F) in February. More severe cold temperatures during winter and warmer temperatures during summer are found inland. Much of the North Slope experiences -40°C (-40°F) and in localized interior areas, temperatures may plunge to -54°C (-65°F). The %°C warmest month isotherm roughly follows the arctic coast while the 10°C isotherm runs parallel to the 5° line but is found some 240 km (150 mi.) inland (Nordenskjold, 1928).

Wind is a common occurrence and when combined with cold ambient air temperatures of the area, has serious implications; chill factors greater than -73°C (-100°F) have been recorded, which make living and working out-of-doors virtually impossible. Wind is also responsible for redopositing a substantial percentage of snow that falls during winter. This is important because it removes insulation in some areas and deposits it in others. As a result, the freezing and thawing rates and timing are altered.

Precipitation in Arctic Alaska is much lower than is generally realized. Northern and northwest Alaska may collect as little as 10 cm (4 in.) per year while southern coastal areas of Alaska may receive as much as 500 cm (200 in.) (Johnson, et al., 1969). Furthermore, the precipitation that is deposited during the winter is often moved considerable distances and redeposited by the common and sometimes high winds.

The precipitation that the North Slope receives and the timing of the seasonal melt and discharge has led to misconceptions about the amount of water available. Until recently, most people visited the North Slope during

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the summer period when the sizeable rivers are discharging large volumes of generally desirable water. What is not realized is that the water that is being discharged during the short summer period is the precipitation that accumulated during the long winter. Also, the rivers that flow so abundantly during the summer, commonly have very low discharges during the winter or, in some instances, may cease flowing entirely.

Another dominant feature of the arctic climate is the available light. This factor is dependent upon latitude and season. Point Barrow, about 70°N latitude, had continuous daylight from the middle of May to the first of August but has no daylight from mid-November to about mid-January. Fairbanks, about 65°N latitude, has 20 to nearly 22 hours of daylight from mid-May through most of July, and as little as 3.5 hours in December.

In general, the most memorable features of the winter climate are the darkness, deep cold, wind and the length of the season. By contrast, the summer features weeks of continuous daylight, extensive and frequent fog banks along the coast, water saturated soils along the coast, and daily temperatures that may climb into the 60's (°F) (Sater et al., 1971).

PHYSIOGRAPHY

Three physiographic provinces on the North Slope have been described by Payne, et al. (1951), and Wahrhaftig (1965), and investigated extensively by U.S. Geologic Survey teams (Dutro, 1957). The southernmost of the three is the glaciated Arctic Mountain Province which contains the Brooks Range section which consists of metamorphic, igneous and sedimentary rock including limestone, shale, chert conglomerate and sandstone originating in the Precambrian through Cretaceous eras.

North of the Mountain Province is the glaciated Arctic Foothill Province which contains two sections: the Nothern Foothills and the Southern Foothills. These two sections consist of two parallel belts of hills collectively about 120 km (75 mi.) wide with hills ranging from 150 m (540 ft.) to 667 m (2,000 ft.) in altitude. Both belts of hills consist of moraine and non-moraine rocks, including shale, limestone, sandstone, conglomerate bentonite and tuff. The Northern Foothills contain "Appalachain" type folds in the Lower and Upper Cretaceous aged strata but the Southern Foothills consist of thick deposits of sedimentry nature that have been folded, commonly overturned toward the north and broken by reverse faults.

The third and northernmost province is the unglaciated Arctic Coastal Plain which is underlain by gravels and sands of the Pleistocene Gubic formation which usually becomes more moraine toward the north.

PEDOLOGY

Arctic soils and vegetation types have obvious effects on the appearance of the arctic tundra as well as more subtle but significant effects on interrelationships of temperature equilibrium and permafrost and hydrology.

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The classification of arctic soils has been worked out by Tedrow and Cantlon (1958), and by Tedrow et al. (1958). Based on their work, several general patterns of soil are found. Tundra soil is the most common and is found in all three physiographic provinces. It is characterized by thawing to a depth of about 30 cm (Drew et al., 1958), and has silty, wet and predominantly acid conditions. Tedrow (1973) recognizes four major horizons in the tundra soil: organic surface horizon, mineral soil, buried organic horizon, and frozen substrate.

Bog soil is found extensively in the Coastal Plain and along rive courses in the foothills. This soil is characterized by thick deposits of organic material (up to 9 m), usually acid in reaction, which may contain high percentages of water and by permafrost within 30 cm of the surface.

A third classification is arctic brown silt which, as the name states, is generally brown. The soil is characterized by these features: dark brown loam in the upper horizon grading to dark grey in the third horizon, thick active zone with relatively high temperatures, well drained horizons with low order of leaching, and surface horizon reacting acidic but alkaline conditions existing in lower horizons.

Other more restricted and less common soil types include well-drained, podzol, Randzina, Shumgite, Grumsol and Ranker.

PERMAFROST

Permafrost is one arctic phenomenon that is presently receivng extensive investigation because of its instability when disturbed during the course of construction. The ramifications and importance of this subject are too numerous to mention here; however, an excellent gathering of investigators' results has been produced in the Proceedings of the Permafrost International Conference (1963). Ferrians (1969) places up to 85 percent of Alaska in the permafrost zone with all of the arctic being in the continuous permafrost zone. Permafrost thickness varies from more than 433 m (1300 ft.) at Barrow to discontinuous lenses less than 30 cm (1 ft.) thick at the southern permafrost border in interior Alaska.

Surface mat disturbance and subsequent melting of permafrost has led to investigation of the relationships between permafrost, soils and vegetation. Benninghoff (1952) states that vegetation has an effect on the permafrost in that the energy flux boundary between the atmosphere and the terrestrial surface is equal to the height of the vegetation plus the thickness of the humus and the root system beneath. Effectiveness of this insulating layer is reduced, however, when the surface mean annual temperature is depressed below freezing. Brown (1936a) relates that the mean annual ground temperature is several degrees warmer than the mean annual air temperature with net radiation, vegetation, snow cover and ground thermal characteristics varying with time. This factor indicates that thermal equilibrium has not yet been reached between the permafrost and the atmosphere.

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Walker and Arnborg (1969) examined permafrost temperatures in ice-wedge polygons near Point Barrow. Ground temperatures at the 3.5 m depth ranged annually from -5° to -15°C, and at the 7.5 depth from -8° to -11°C, a smaller annual variation. Lachenbruch et al. (1962), describe the relationship between temperature and permafrost in more detail.

A complex community of plants interrelate with each other and the physical and chemical environment to affect permafrost. About 300 species of plants have been identified by Johnson et al. (1964), from the Ogoturok Creek Valley, located 68°05'N, well within the continuous permafrost zone as defined by Sumgin (1927). Johnson (1963) discusses several interrelationships between permafrost and vegetation and suggests that permafrost: (1) impedes drainage of water into the underground aquifer; (2) maintains low temperatures in the root zone during the growing season and restricts the root systems to the active frost zone; and (3) provides an impervious substrate similar to bedrock. He also states that permafrost related soil ice can lead to development of thermokarst topography as ice melts. This condition is dependent upon the relationships that the vegetation: (1) dampens the soil temperature extremes; (2) maintains the permafrost levels; (3) retards the penetration of heat into soil in the spring, and loss of heat in the fall; and (4) retards the rate of soil and frost erosion due to melting. Brown (1936b) concludes that heat and moisture reactions involving the vegetation-permafrost relationship are physically reversible.

Whereas Brown (1936b) discusses the variability of heat and moisture relationships on the surface, other investigators have indicated that geothermal characteristics may vary from area to area. Brewer (1958a, 1958b) recorded thermal gradient ranges from 1°F/72 ft. to 1°F/324 ft. depending upon the rock type. Shpolyanskaya (1962) investigated the gradient in sedimentary rock in the Transbaikal region in the USSR and recorded 1°F/37 ft., similar to Brewer's (1958a) results at Barrow.

GLACIATION

Glaciers from the Brooks Range were initially described by Schrader (1902). Glaciology and physiography of the Canning River region were described in detail by Leffingwell (1919). Detterman (1953) was the first to propose the names Anaktuvik, Sagavanirktok, Itkillik and Echooka glaciations for the Quaternary glaciations that advanced in the Sagavanirktok-Anaktuvik region.

Three glacial depoists are found in the Sagavanirktok River basin. The Sagavanirktok deposit is found further down the drainage than the Itkillik and Echooka deposits. Namesake deposits are found from the Brooks Range to the mouth of the Lupine River and in the Ivishak River subdrainage northward to the confluence with the Echooka River about 40 km (25 mi.) north of the Brooks Range. The Itkillik deposits have smaller southern distribution and the Echooka deposits are even more restricted to higher altitudes. Detterman (158) dates the Sagavanirktok deposits in the Pre-Wisconsin geologic period and the Echooka and Itkillik in the Early Wisconsin period.

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Dynamic ice formations and associated effects have influenced the formation of different types of lakes. Glacial moraines deposited by advancing glaciers and abandoned by retreating ice fields have played an important role in the formation of high altitude lakes, such as Galbraith and Peters Lakes, in the Brooks Range and Foothills Province. These lakes are typified as being oligotrohic, with short open water periods during the summer, low in total dissolved solids (Sater, 1971), and usually less than 20 m (60 ft.) deep (Holmquist, 1967). Buried glacial ice that is melting causes formation of kettle lakes as described by Detterman et al. (1958), and Livingstone et al. (1958). These bodies of water are also found in the Foothills Province and are frequently oligotrophic. Thermokarst lakes cover an estimated 50 to 75 percent of the surface area in the Coastal Plains (Black and Barksdale, 1949). These shallow oriented lakes are formed by the melting of permafrost (Livingstone, 1954), are usually less than 3 m deep and have water that is distinctively brown in color.

Dissolved oxygen is probably the most important parameter in all these waters. Sater (1971) states that the oxygen content of fresh waters in the Arctic is usually high due to the constant mixing that ensures oxygen saturation during the summer, while the small amount of organic material that has been deposited and the low temperatures may prevent oxygen deficiency during the winter. Recent studies (Schallock and Lotspeich, 1974) indicate, however, that winter low dissolved oxygen concentrations do occur in rivers. Observations of dead fish on lake beaches in early spring leads to the conclusion that winter kill occurs in lakes.

PREVIOUS LIMNOLOGICAL WORK

The first limnological work in Alaska was carried out by Firge and Rich (1927) on Karluk Lake in response to concern about a declining salmon fishery on Kodiak Island. Early limnology in Canada was conducted by Johansen (1922) on the crustaceans of arctic lakes and ponds. A need to investigate arctic waters before development drastically changes the fragile environment was stated by Reed (1953). Few studies had been conducted up to this time. Impending industrial development of the Arctic focused attention on the area and led to the realization that little information was available.

Much of the information that was subsequently collected centered around the physical, chemical and biological characteristics of tundra ponds and lakes. The origin and development of Alaskan ponds and lakes has been discussed by Black et al. (1949), Carson, et al. (1962), Hutchinson (1957), and Livingstone (1954 et al., 1958, 1963). General chemical characteristics of lakes and occasional rivers have been reported by Boyd (1959), Hobbie (1960), Livingstone et al. (1958), Moore (1949), and by Wells and Love (1957, 1958a, 1958b). Nutrient chemistry relationships have been presented by Barsdate (1967), Dugdale (1965), Kalff (1968), Lomar (1966), and Livingstone et al. (1958).

The fauna and flora of some aquatic systems have already been documented. Aquatic vascular plants have been described in a compendium by Hulten (1940-1950). Algae from several Alaskan and Canadian areas were discussed by Hilliard (1959 et al., 1966), Prescott (1953, 1965a, 1965b), Taylor (1954),

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and Whelden (1947). Several detailed studies have described zooplankton found in Alaskan ponds and lakes. Wilson (1953, 1965, 1966 et al., 1966) described copepod populations and distributions. Sommerman (1953, 1958, 1961) described and discussed the taxonomy of Simuliidae. Bousfield (1958) presented Amphipoda of North America which contained some Canadian data. More detailed life history studies were made on planktonic copepoda and cladocera by Comita (1956) and Edmonson (1955) respectively. A limited number of life history studies and distribution patterns of fishes in northern areas have been published. Age, growth rate, mortality rate and metabolic rates of arctic whitefish have been described by Cohen (1953) and Wohlschlag (1953, 1954, 1957). Growth, maturity and mortality of lake trout from Great Slave Lake have been presented by Kennedy (1957). Taxonomy and general distribution of fishes in northern areas have been discussed by McPhail et al. (1970), Wilimovsky (1954, 1958), and Wynne-Edwards (1952). Recently, additional information on North Slope fishes have been gathered but much of these data is in tabular form. McCart et al. (1972) concluded a study on arctic char.

Several areas of the limnological ecosystem have virtually been totally neglected. Only scattered physical and chemical data have been collected from arctic rivers. Furthermore, little is known about the invertebrate biota of these northern rivers. Algae and macrobenthic studies have not been conducted. This study is intended to partially fill the gap in the limnology of running waters.

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SECTION IV

PROJECT DESIGN AND OBJECTIVES

LOCATION OF THE SAGAVANIRKTOK RIVER STUDY AREA

The Sagavanirktok (Sag) River basin is located in the eastern third of the Alaska North Slope. Waters of the Sag River basin originate in the Philip Smith and Endicott Mountains which range from an eastern longitudinal at approximately 146°15'W to the western boundary at approximately 150°00'W. The water travels at a distance of 400 km (250 mi.) over a latitudinal range from 68°05'N to 70°20'N and passes through all three physiographic provinces.

The Sagavanirktok River is fed by Galbraith Lake via the Atigun River and by the Ribdon, Ivishak, and Lupine Rivers, and Accomplishment Creek, that drain toward the west from the small glaciers in mountains rising to 7,500 ft. Annual high surface discharge and high turbidity of the year usually appear during the spring breakup in June, and with some variation due to rain, both gradually decrease throughout the summer. However, Brewer (1958a) reports that even after the snow has melted, light widespread rain can result in near flood conditions because most water runs off rapidly to the river systems. Minimal discharges of the year are recorded during winter (U.S. Geological Survey, 1970). Ice cover usually forms in September and remains until May or June, for a total of 240-260 days covered with ice (Anonymous, 1946).

The Canning River is approximately 125 km east of the Sagavanirktok River main stem. The waters of the Canning River originate in the Shublik Mountains, Franklin Mountains and Philip Smith Mountains some 175 km to the south and flow virtually parallel to those of the Sag River. The Shaviok River is located about midway between the Canning and Sagavanirktok Rivers. The drainage basin of this river is narrow and considerably smaller than either the Canning or the Sag because of the Accomplishment and Ivishak tributaries of the Sag on the west, the Kavik River on the east, and the headwaters of both the Canning and Sag Rivers which meet in the Phillip Smith Mountains to the south of the Shaviovik. The majority of the Shaviovik is located about equally in the Southern and Northern Foothills of the Arctic Foothill Province.

GENERAL OBJECTIVES

This study was designed to establish baseline levels of biological, chemical and physical parameters in the Sagavanirktok River and adjacent streams, before more intensive industrial activities further alter the aquatic environment. Ultimately this information may provide a basis for future management decisions and for comparison with subsequent future studies.

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Data from the Sagavanirktok River are compared to those of the Canning River which was chosen as the control of the investigation because the pristine state of its drainage and waters permits a comparison to the somewhat more inhabited Sagavanirktok River system. Also, the eastern drainages of the Canning River are within the Arctic Wildlife Range which has prescribed limitations on some of mans' modes of travel and endeavors; as a result of the status of the encompasses lands should remain unchanged.

In addition to the Sagavanirktok River and Canning River, several other streams and bodies of water were included in the study. The Shaviovik River and four tributaries of the Sag River (Atigun, Ribdon, Lupine and Ivishak) were sampled to examine differences that may be found between the larger drainages, such as the Sag River, and smaller subdrainages. Three lakes--Galbraith, Nora Fed No. 1 and Nora Fed No. 2, were selected to be studied because of their location with the Sag River drainage and because these lakes are of two different morphological types. Galbraith Lake is classified as oligotrophic, as characterized by Sater (1963). Nora Fed Lakes No. 1 and No. 2 are thermokarst lakes, as described by Black and Barksdale (1949) and Livingstone (1954).

AQUATIC BIOLOGY OBJECTIVES

The aquatic biology segment of the project focused on stream macrobenthos and smaller efforts were directed to coliform bacteria, phytoplankton, lake macrobenthos and piscifauna. Major taxons of the macrobenthic community were enumerated and identified. Total coliform bacteria were sampled and enumerated to identify any pathogen problems in the water. Phytoplankton were collected and identified. Piscifauna were to be sampled and identified whenever possible. Limited correlations are made between biological phenomenon and physical-chemical characteristics.

CHEMICAL AND PHYSICAL OBJECTIVES

The specific objectives of the chemical and physical segment of the study were to examine those parameters essential to define the water quality in these pristine waters and to relate them to primary production and nutrient limitations affecting biological community dynamics. Of particular interest in the arctic are the effects of the rigorous climate on the aquatic environment. More specifically these parameters were investigated: the relationships between ground and surface water sources in summer and winter; the effect of ice cover and temperature on dissolved oxygen and the relationship between chemical water quality and biological populations. The latter is extremely complex and little understood.

SECTION V

METHODS

AQUATIC BIOLOGY METHODS

Field trips and collecting procedures were designed to sample invertebrate populations at different times of the year and thereby establish population abundance and diversity within the year. As a result, two sampling trips were taken: one in June immediately after the crest of the spring runoff, hopefully before insect emergence; and the second trip in late August to sample when emergence had virtually ceased. A total of 13 stations along the Sagavanirktok River, 4 stations on the tributaries, 4 stations on the Shaviovik River and 3 stations along the Canning River were sampled to examine changes along reaches of the rivers and to compare the biota of several rivers (Table 1).

The macrobenthic community was given the highest priority because members of this group are relatively immobile, although not sessile, which makes this community the most probable recipients of effects of pollution. Special emphasis was placed on enumerating and identifying five groups--Plecoptera, Ephemeroptera, Trichoptera, Diptera (primarily Chironomidae), and Annelida. With the exception of Annelida, these were usually identified to genus. Other organisms found in the macrobenthos samples were generally identified to the family taxon. Most macrobenthic taxonomic determinations were made on immature forms which leads to problems since the most definitive keys are based on adult organisms. As a result of this factor and additional work that will be done, it is anticipated that changes will be made in this list of organisms.

Microbiology, phytoplankton and fisheries received less effort because of a combination of personnel and funding limitations. Sanitary microbiology consisted of testing for fecal and total coliform bacteria; algology entailed collecting phytoplankton, principally Bacillariophyceae; and wherever possible, fishery biology involved collecting, enumerating and identifying the endemic fishes.

When examining the macrobenthos, three quantitative Surber samples were collected from representative substrate at each station. It is recognized that the number of Surber samples needed to obtain high confidence levels, as discussed by Needham and Usinger (1956), is significantly greater than three. However, time and cost limited the sample number to three which Cutter and Noble (1966) concluded is adequate to describe numbers and composition. Composite qualitative samples were collected by sampling the different ecological niches with a triangular shaped dipnet. All samples were fixed at the field station using approximately 10 percent formaldehyde.

TABLE 1. LOCATIONS OF SAMPLING STATIONS IN THE SAGAVANIRKTOK RIVER STUDY (1969-1970)

		Station
Sagavanirktok River		
Channel Below BP 31-11-16	East	S-100
	West	S-200
Channel Above Toolik Fed #1	East	S-300
	West	S-400
Franklin Bluffs		S-500
Below Nora Fed #1		S-600
Below Ivishak Confluence		S-700
Below Sagwon		S-800
Above Sagwon		S-900
Below Ribdon Confluence		S-1000
Above Ribdon Confluence		S-1100
Below Atigun Confluence		S-1200
Above Atigun Confluence		S-1300
Atigun River		
Below Galbraith Lake		A-100
Above Galbraith Lake		A-200
Ribdon River		
Above Confluence with Sagavanirktok River		R-100
Ivishak River		
Above Confluence with Sagavanirktok River		I-100
Shaviovik River		
Approximately 10-20 Miles Below Well		SH-100
Approximately 2 Miles Below Well		SH-200

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TABLE 1 (continued)

Directly Above Well Airstrip	SH-300
Upper Station Above Well, West Side of Shaviovik River	SH-400
Canning River	
Near Mouth	CA-100
Above Delta	CA-200
Red Hill Area; Oil Field on West Side, Wildlife Range on East Side	CA-300
	Depth
Galbraith Lake	
Approximately 100 Yards into Lake from Western Inlet	0 Meters
Approximately 100 Yards Upstream from Confluence with Atigun River	Outlet
Nora Fed #1	
Lake Area, Northeast Side Near End of Airstrip	0 Meters
Nora Fed #2	
Lake Area, Off South Bank	0 Meters

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Once the samples were returned to the base field camp at Sagwon, the organisms were separated from the associated debris by utilization of the flotation method developed by Anderson (1959). Simultaneously, organisms were sorted into classes, placed in vials and preserved in Hood's solution for future taxonomic work to be performed at EPA's Arctic Environmental Research Laboratory (AERL). At AERL, this taxonomic endeavor consisted of identifying specimens to genus although some groups or Diptera were identified to family, while annelids and miscellaneous groups were identified to class.

Free-floating plankton were quantitatively collected by sampling for exactly 5 minutes with a Wisconsin plankton tow in similar water velocities. These samples were immediately flushed out of the bucket into widemouth babyfood jars and fixed with 10 percent formaldehyde solution. Once fixed, the samples were retained until subsequent cleaning and mounting on slides at the laboratory. Representative samples were identified.

Microbiological samplings and subsequent analyses were conducted while in the field and according the Standard Methods (A.P.H.A., 1971). All microbiological sampling utilized grab techniqes and sterilized 200 mm containers. While in the field, these containers were immediately placed in insulated boxes and refrigerated with ice until handling and analysis at the base camp field station. At camp, samples were filtered utilizing standard membrane filtering techniques. The filters containing the filterable organisms were then places on agar growth media and allowed to incubate for 24 hours at 35°C. The plates were then counted and the results recorded.

Piscifauna populations were examined using both qualitative and quantitative techniques. The quantitative measures included personal and angler observations of the relative number, size, type of fish and location. Occasionally rod and line sampling was used to demonstrate that fish were present. Quantitative sampling consisted of 125-feet variable mesh experimental monofilament gill net. For each gill net set, these data were recorded: the length of time that the net was fishing; the number, type and size of captured fish. All specimens were frozen at the base camp for later examination at the AERL facilities.

CHEMISTRY METHODS

Samples collected for chemical analysis were all surface grab samples from well-mixed areas. In those areas of stream confluence where complete mixing was questioned, the stream was traversed with a field conductivity meter and continuously monitored to note any anomalies.

Samples collected for dissolved oxygen determinations were fixed with alkaline-iodine-azide solution and manganous sulfate in 300 ml standard BOD bottles immediately after being taken. They were returned to the field laboratory at Sagwon where the determination was completed using the azide modification of the Winkler Method (A.P.H.A., 1971).

Conductivity was measured in the field with a bridge-type meter and pipet cell; values were internally corrected to 25°C.

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The pH was measured using a null balancing field meter with standard glass measuring and fiber junction electrodes. Temperature was measured with a mercury-in-glass thermometer previously calibrated against a National Bureau of Standards thermometer.

Samples for later analysis at the Arctic Environmental Research Laboratory were collected in acid washed polyethylene containers. Samples for nutrient analysis were frozen to -20°C soon after collection, and were stored at this temperature until analyses were performed. Samples for metal analyses were preserved by addition of 10 ml/l hydrochloric acid. Those analyzed for nitrate, nitrite, ammonia and orthophosphate were filtered through a membrane filter prior to freezing. Methods of analysis were *FWPCA Interim Official Methods* (1969).

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SECTION VI

AQUATIC BIOLOGY

MACROBENTHIC COMMUNITY ALONG SAGAVANIRKTOK RIVER MAIN STEM

The macrobenthic community of the Sag River was usually numerically dominated by one of the following groups: Plecoptera, Ephemeroptera, Trichoptera, Diptera (Chironomidae) and Annelida. At any particular station, the importance of each of these groups may change but these five taxons of unequal rank usually accounted for the majority of the total numbers and occasionally the observed biomass at any particular station. Biomass generally follow the total number pattern although occasionally a small number of comparatively large organisms such as Tipulidae or Cottidae, may account for the biomass dominance while another group may be numerically important.

The members of these taxa are important because they contribute substantially to the diet of grayling (Schallock, 1965a; Wojcik, 1953) and other fishes. Although data on Alaskan char and whitefish are not available, it is probable that these fishes feed on these organisms since Nilsson (1960) reports the char and whitefish found in northern Sweden utilize them as food.

Plecoptera

The class Plecoptera, stoneflies, is represented by three families: Nemouridae, Perlodidae, and Chloroperlidae (Table 2 and Table 3). Perlodidae contains three genera, *Arcynopteryx sp*, *Isoperla sp*, and *Isogenus sp*; Chloroperlidae has two genera, *Alloperla sp* and *Hastaperla sp*. Nemouridae is represented by *Nemoura sp*, *Capnia sp*, *Isocapnia sp*, *Brachytera sp*, and *Eucapnopsis sp*.

During early summer, June and July, these families or genera were not uniformily distributed along the entire reach of the river. The family Nemouridae was widely distributed and generally most abundant at any particular station. Of the five genera in Nemouridae, *Capnia sp* and *Nemoura sp* were the most abundant and were distributed over the entire reach of the river. Occasional specimens were collected at S-100, so some tolerance to increased salinities, although perhaps temporary, is possible. Invertebrate drift may also explain this distribution. The remaining three genera, *Brachyptera*, *Isocapnia* and *Eucapnopsis* were less abundant and more narrowly distributed in a belt from Franklin Bluff south to above Sagwon.

Perlodiadae were widely distributed although not necessarily the most numerous; this taxa has been found from S-100 near the mouth of the river, to S-1300 in the Brooks Range. From this family, *Arcynopteryx* and *Isogenus* have been collected at S-100 and apparently tolerate the salt water that probably

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TABLE 2. QUALITATIVE BIOLOGICAL DATA FROM 13 STATIONS ON THE SAGAVANIRKTOK RIVER, JUNE 1969

ORGANISM Class Family	Station Numbers												
	1300	1200	1100	1000	900	800	700	600	500	400	300	200	100
PLECOPTERA													
Perlodidae	X	X	X	X	X	X	X	-	X	X	X	-	X
Chloroperlidae	-	-	-	X	-	-	X	X	X	-	-	-	-
Nemouridae	X	X	X	X	X	X	X	X	X	-	X	-	X
EPHEMEROPTERA													
Baetidae	-	-	-	X	-	-	-	-	-	-	-	-	-
Heptagenidae	-	X	X	X	X	X	X	X	X	-	X	-	X
Siphlonuridae	X	X	X	X	X	X	X	X	X	-	-	-	-
Ephemerellidae	-	-	-	-	-	-	-	-	-	-	-	-	-
TRICHOPTERA													
Brachycnetridae	-	-	-	-	-	-	-	-	-	-	-	-	-
Limnephilidae	-	-	-	-	-	-	-	-	-	-	-	X	-
DIPTERA													
Chironomidae	X	X	X	X	X	X	X	X	X	X	X	X	X
Tipulidae	-	-	X	-	X	-	-	-	X	X	X	-	X
Simuliidae	-	-	X	X	-	-	-	-	-	-	-	-	-
Ceratopogonidae	X	X	X	X	X	-	-	X	-	-	-	-	-
Brachycera (suborder)	X	X	X	X	X	X	-	-	-	X	-	-	X
ANNELIDA	-	X	X	X	-	-	-	X	-	X	X	-	X

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TABLE 3. QUALITATIVE BIOLOGICAL DATA FROM 13 STATIONS ON THE SAGAVANIRKTOK RIVER, AUGUST 1969

ORGANISM Class Family	Station Numbers												
	1300	1200	1100	1000	900	800	700	600	500	400	300	200	100
PLECOPTERA													
Perlodidae	X	X	X	X	X	X	X	X	-	X	X	-	X
Chloroperlidae	-	-	-	-	-	-	-	-	-	-	-	-	-
Nemouridae	X	X	X	X	X	X	X	X	X	-	X	-	X
EPHEMEROPTERA													
Baetidae	X	X	X	X	X	X	X	X	X	X	X	X	X
Heptagenidae	X	-	X	X	X	X	X	X	X	X	X	-	X
Siphlonuridae	X	X	-	X	X	X	X	X	X	-	X	X	X
Ephemerellidae	-	X	X	X	X	X	X	X	X	-	-	-	-
TRICHOPTERA													
Brachycnetridae	X	X	X	-	-	-	-	-	-	X	-	-	X
Limnephilidae	X	X	X	X	X	-	-	X	-	-	-	-	X
DIPTERA													
Chironomidae	X	X	X	X	X	X	X	X	X	X	X	X	X
Tipulidae	-	X	X	X	X	-	X	X	-	X	-	-	X
Simuliidae	X	X	X	X	X	X	X	X	X	-	X	-	-
Ceratopogonidae	X	X	X	X	X	X	X	X	X	X	X	X	X
Brachycera (suborder)	-	-	X	X	-	-	-	-	X	-	X	X	X
ANNELIDA	X	X	-	X	X	X	-	X	-	X	-	-	X

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intrudes under some conditions from the Beaufort Sea. *Isogenus* was continuously distributed from the coast to the Brooks Range but *Arcynopteryx* was found only to the Foothill Province south of Sagwon. *Isoperla* was the least abundant and was found from Sagwon to the Brooks Range, thereby overlapping the distribution of *Arcynopteryx* and *Isogenus*.

The family Chloroperlidae was the least abundant of the three families. Its two genera, *Alloperla sp* and *Hastaperla sp*, were found only in a belt from Franklin Bluffs, S-500, south to Ribdon River area, S-1000.

The distribution and diversity of the stonefly community changes during the summer. At the family level of taxonomy, the June and August distribution of Perlodidae appears similar but the August distribution was primarily due to *Isogenus* because both *Arcynopteryx* and *Isoperla* were not found at that time. Chloroperlidae also was not collected during August but Nemouridae and the four contained genera maintained a similar distribution pattern throughout the sampling periods although slightly more abundant in the habitat of the Foothill Province and Brooks Range Province.

Plecoptera Summary

Plecoptera fauna was represented by three families and nine genera. Nemouridae was, with four genera, the most important family and was usually numerically dominant although Perlodidae occasionally dominated the observed biomass.

Three genera, *Capnia*, *Nemoura* (Nemouridae) and *Isogenus* (Perlodidae) were found in increasing numbers from the Beaufort Sea to the Brooks Range. These and *Arcynopteryx* (Perlodidae) may possess some tolerance to the summer salt water intrusion near the coast. The remaining six genera were found in smaller numbers and had more restricted distributions with four genera found only in a Foothill Province belt from Franklin Bluffs to south of Sagwon.

Ephemeroptera

The class Ephemeroptera, mayflies, is represented by four families, Baetidae, Heptagenidae, Siphlonuridae, and Ephemerellidae (Tables 2 and 3). Baetidae consisted of four genera, *Baetis sp*, *Centroptilum sp*, *Pseudocleon sp*, and *Apobaetis sp*. Heptagenidae also contained four genera, *Cinygmula sp*, *Rithrogena sp*, *Epeorus sp*, and *Cinygma sp*. Siphlonuridae contained *Ameletus sp*, and *Siphlonurus sp* and Ephemerellidae was represented by *Ephemerella sp*.

During June and July, three families (Baetidae, Heptagenidae, Siphlonuridae) were widely distributed but represented by small numbers of individuals and not all of the genera. Within Baetidae, the numerically dominant genus, *Baetic*, was found from S-100 to S-1000, *Centroptilum* was generally distributed continuously south of the Ivishak River (S-700); and *Pseudocleon* and *Apobaetis* were sporadically located along the entire Sag River. Heptagenidae was widely distributed and represented continously by *Cinygmula*, represented rarely by *Cinylma*, while *Rithrogena* and *Epeorus* were not found. Of the two genera of Siphlonuridae, *Ameletus* was widely distrib-

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uted south of Franklin Bluffs and *Siphlonurus* was rarely encountered. Ephemerellidae was entirely absent from the macrobenthic community at that time.

The distribution and diversity of the Ephemroptera fauna changed during the summer. By late August and early September, the diversity and distribution of Ephemeroptera had increased to three families, Baetidae, Heptagenidae, and Siphlonuridae which were distributed from the Beaufort Sea to the Brooks Range and in addition Ephemerellidae was found south from Franklin Bluffs. Baetidae was represented at each station by *Baetis*; *Centroptilum* was less abundant; and *Pseudocleon* and *Apobaetis* were rarely encountered. *Cinygmula* was the principal mmber of Heptagenidae with *Epeorus* and *Rithrogena* less abundant and sporadically distributed. The distribution of Siphlonuridae, mainly *Ameletus* expanded to north of Franklin Bluffs. Ephemerellidae, *Ephemerella*, was found south from Franklin Bluffs to the Brooks Range.

Ephemeroptera Summary

Ephemeroptera was represented by four families and eleven genera. Early summer Ephemeroptera fauna was dominated by *Baetis* (Baetidae), *Cinygmula* (Heptagenidae), and *Ameletus* (Siphlonuridae). By late summer, the diversity and distribution generally had increased although some genera that were found earlier were not encountered. *Baetis*, *Cinygmula*, and *Ameletus* were still the dominant genera. A genera and family that had been absent earlier, *Ephemerella* (Ephemerellidae) was also present.

Trichoptera

The Trichoptera, caddisfly, fauna of the Sag River was relatively sparse both in numbers and diversity. Two families, Brachycentridae and Limnephillidae, contained three genera that were generally sporadically distributed (Tables 2 and 3).

During June and July, only *Drusinus sp* of the family Limnephilidae was found and then only at S-200. However, both the diversity and distribution of caddisflies increased somewhat by late summer. Although sporadically distributed, *Drusinus sp* populations were found along the entire river by August. The second genus within Limnephilidae, *Raema sp* was found continuously from Sagwon south to the mountains. The only genus within Brachycentridae, *Brachycentrus sp* was discontinuously distributed from the Coastal Plains Province to the Brooks Range Province.

Trichoptera Summary

Trichoptera, represented by two families and three genera, were sparse in both diversity and numbers. In early summer, only *Drusinus* (Limnephilidae) was sporadically found, but in late summer, another *Limnephilid*, *Radema*, and one Brachycentrid, *Brachycentrus*, were found but each was also sporadically distributed.

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Diptera

Within the order Diptera, a total of 11 taxons, 10 families and 1 suborder have been collected from the Sag River. Five of these taxons dominated the Diptera fauna and sometimes dominated the total collection of all aquatic invertebrate forms. These five, the suborder Brachycera, and the families Tipulidae, Simuliidae, Ceratopogonidae, and Chironomidae have been tabulated in Tables 2 and 3.

Some member of the order was found at all stations throughout the summer but the distribution of individual groups generally changed somewhat during the summer. Chironomidae was ubiquitously distributed along the entire river during both June and August and at times was the numerically dominant organism. On rare occasions Chironomidae also dominated the observed biomass. A total of 14 species or subspecies have been identified at this time and are listed in a subsequent section. Additional taxonomic efforts will cause changes in this list. The suborder Brachycera was found at most stations in both early and late summer. Ceratopogonidae was collected only occasionally during June but was found continuously in August. The distribution of Tipulidae did not change during the summer season but the frequency of occurrence was greater during August. The most dramatic increase was found in Simuliidae. In June, Simuliidae was collected only near Sagwon, but in August the family was found along the entire river with the exception of the two stations at the mouth.

Diptera Summary

Diptera fauna is represented by ten families and one suborder. The most important family is the Chironomidae which at times may numerically dominate the sample. All groups could generally be collected at any station but Tipulidae, Ceratpogonidae, and Brachycera were collected sporadically. Simuliidae was collected at two stations in June but in August was found all along the river except near the mouth.

Annelida

The order Annelida was ubiquitous in the Sag River drainage. This group includes the freshwater and nonparasitic forms. At times hard to find, at other times readily collected, annelids may represent a significant percentage of the observed biomass of a particular sample and are included for this reason. These organisms were sporadically collected along the entire reach of the Sag River but were generally not abundant.

Macrobenthic Community Diversity and Quantitative Patterns

The benthic macroinvertebrate data collected prompts several generalizations about the diversity and quantitative patterns exhibited by the aquatic biota of the Sagavanirktok River.

Both the number of organisms per square foot and the number of genera per sample station appeared to increase from the mouth (Stations S-100 and S-200) to the headwaters (Station S-1300). The smallest number of organisms was found at Station S-200, near the mouth of the river on the western edge of the braided area. The largest number of organisms (somewhat of an anomaly and due to an atypical number of Chironomidae appeared at Station S-100 which is also near the mouth of the river but on the eastern limit of the braiding and in an area that was relatively undisturbed. Upstream from these two stations near the mouth, the biota generally increase both in number of organisms per square foot and number of genera present. At Station S-1300 on the Sagavanirktok River upstream from the confluence with Atigun River, the total number of organisms and total genera present are approximately five times that of Station S-200. The upper reaches of the Sagavanirktok River, therefore, appears to be significantly more productive.

Numbers of organisms found in June and August were compared. June quantitative sampling consistently and sometimes drastically had more organisms than the August set. Occasionally stations such as S-100, S-400 and S-1100 showed significant divergences from that trend. While the divergences may be large, they may not be indicative of the true situation because of their relatively wide divergence from the trend demonstrated by adjacent stations. Each of these instances are due to numbers of Chironomidae.

Numbers of genera at each station were also compared for June and August. Although the June set had more organisms in the quantitative samples, the August set derived from qualitative samples consistently contained more genera. The differences ranged from only slight increases to a factor of several times. This comparison is significant because, in examining a benthic community, it indicates that bias could easily be introduced into the sample. It is important to pick the proper sampling station as well as the appropriate time of year if the quantitative and qualitative sampling procedures are to be representative and qualitative sampling procedures are to be representative of the benthic biota. In those instances where the organisms was identified to taxons other than genera (i.e., family, order), the assumption was made that only one genus was present. Obviously, additional determinations will result in higher diversity and conceivably an even higher ratio when comparing the upper reaches of the river to those near the mouth.

SAGAVANIRKTOK RIVER TRIBUTARIES MACROBENTHIC COMMUNITY

Plecoptera

Three families of Plecoptera, Nemouridae, Perlodidae, and Chloroperlidae were found in the Ribdon, Lupine and Lvishak Rivers during June but at that time only Nemouridae was found in the Atigun River (Table 4). The distribution in August was somewhat different; Chloroperlidae were absent, Perlodidae and Nemouridae were generally found in the tributaries although the latter family was not found in the Ribdon River (Table 5).

Ephemeroptera

Four families of Ephemeroptera were found in some tributaries although only three were collected in the Sagavanirktok River mainstem. The additional family, Ephemerellidae was found in the Lupine and Ivishak Rivers (Tables 4 and 5). The most widely distributed abundant families were Baetidae and

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TABLE 4. QUALITATIVE BIOLOGICAL DATA FROM 12 SAMPLE STATIONS ON 6 RIVERS AND CREEKS IN THE SAGAVANIRKTOK RIVER STUDY, JUNE 1969

ORGANISM	Drainage and Station Number											
	Canning River			Shaviovik River				Atigun River		Ribdon River	Lupine River	Ivishak River
Class Family	300	200	100	400	300	200	100	200	100	100	100	100
PLECOPTERA												
Perlodidae	X	X	-	-	-	-	-	-	-	X	X	X
Chloroperlidae	X	X	-	-	-	-	-	-	-	X	X	X
Nemouridae	X	X	X	X	X	X	X	X	X	X	X	X
EPHEMEROPTERA												
Baetidae	-	-	-	X	X	X	X	-	X	X	X	-
Heptagenidae	X	X	X	X	X	-	X	-	X	X	X	X
Siphlonuridae	-	-	-	-	-	-	-	-	-	X	X	X
Ephemerellidae	-	-	-	-	-	X	X	-	-	-	X	-
TRICHOPTERA												
Limnephilidae	-	-	-	-	-	-	-	-	X	-	-	-
DIPTERA												
Chironomidae	X	X	X	X	X	X	X	-	X	X	X	X
Tipulidae	X	X	X	X	X	X	X	X	X	-	X	X
Simuliidae	-	-	-	X	X	X	X	X	X	-	X	-
Ceratopogonidae	X	X	X	X	X	X	X	X	X	X	X	-
Brachytera (suborder)	-	-	-	-	X	X	X	-	-	-	X	X
ANNELIDA	X	X	X	X	X	X	X	X	X	X	X	X

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TABLE 5. QUALITATIVE BIOLOGICAL DATA FROM 13 SAMPLE STATIONS ON 6 RIVERS AND CREEKS IN THE SAGAVANIRKTOK RIVER STUDY, AUGUST 1969

ORGANISM Class Family	Drainage and Station Number												
	Canning River				Shaviovik River				Atigun River		Ribdon River	Lupine River	Ivishak River
	400	300	200	100	400	300	200	100	200	100	100	100	10
PLECOPTERA													
Perlodidae	X	X	X	-	-	X	-	X	X	X	X	X	X
Chloroperlidae	-	-	-	-	-	-	-	-	-	-	-	-	-
Nemouridae	X	X	X	-	X	X	X	X	X	X	-	X	X
EPHEMEROPTERA													
Baetidae	X	X	X	-	X	X	X	X	X	X	X	X	X
Heptagenidae	X	X	X	-	X	X	X	X	-	-	X	X	X
Siphlonuridae	-	-	-	-	-	-	-	-	-	-	-	-	X
Ephemerellidae	-	-	-	-	X	-	X	X	-	-	-	X	X
TRICHOPTERA													
Limnephilidae	-	-	-	-	-	-	-	-	-	-	-	-	-
DIPTERA													
Chironomidae	X	X	X	-	X	-	X	X	X	X	X	X	X
Tipulidae	-	-	X	-	X	X	X	X	X	X	X	X	X
Simuliidae	X	-	-	-	X	X	X	X	X	X	X	-	X
Ceratopogonidae	X	-	-	-	X	-	-	-	X	X	-	-	X
Brachytera (suborder)	-	-	-	-	X	-	-	-	-	X	-	X	-
ANNELIDA	X	X	X	-	X	X	X	X	X	X	X	X	X

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Heptagenidae, although Heptagenidae was not found in Atigun River during August. Siphlonuridae was collected from all but Atigun during June but was absent from all but Ivishak in August.

Trichoptera

The Trichoptera populations of the tributaries were small, restricted in distribution and limited to the family Limnephilidae (Tables 4 and 5). This family was found only in the Atigun River during June and in the Ivishak River during August.

Diptera

The total number of Diptera groups generally increased in all tributaries except the Lupine River during the June to August interval (Tables 4 and 5). This pattern was similar to that of the Sag River. On an individual family basis, some patterns were observed. Chironomidae and Tipulidae were consistently found in all tributaries except Tipulidae which was absent from the Ribdon River in June. Simuliidae was collected from all tributaries except the Ribdon in June and all but the Lupine in August. Ceratopogonidae was present in all streams but Ivishak in June and only in Atigun and Ivishak in August; Brachycera was located in Lupine and Ivishak in June and in Atigun and Lupine in August. Over both sample periods, all tributaries appeared to support substantial numbers and diversity of Diptera.

Annelida

Annelidae was ubiquitously distributed in all tributaries in both sample intervals just as in the Sag River (Tables 4 and 5). The only exception was the Atigun River where annelida was found during June but not during August.

CANNING RIVER MACROBENTHIC COMMUNITY

The distribution patterns of specific groups within the macrobenthic community of the Canning River were similar to those patterns already described in the Sagavanirktok River Section (Tables 4 and 5). Because these patterns have already been discussed, only the differences between the Sagavanirktok River patterns and those in the Canning River will be presented.

Plecoptera

Within the class Plecoptera, only Chloroperlidae show relatively different distribution patterns. This family was more abundant and more widely distributed than in the Sagavanirktok River. In the Sagavanirktok River, the family was confined to the Foothills Province but in the Canning River it was found in the Coastal Plain Province and the Foothill Province.

Ephemeroptera and Trichoptera

The fauna of Ephemeroptera and Trichoptera were less diverse in the Canning River than the Sag River. Two families of Ephemeroptera, Baetidae and Heltagenidae, were found in Canning while four families were found in the Sag

River. Trichoptera was limited to one family, Brachycentridae, and one genus, Brachycentrus, that was found only from the station with the highest elevation at the southernmost location (400).

Diptera

Diptera were represented by four families, the ubiquitous Chironomidae, the seasonally important Tigulidae and Ceratopogonidae and the sporadically distributed Simuliidae. Chironomidae generally dominated the Diptera group from a numerical point of view and occasionally dominated the observed biomass as well.

Annelida

Annelida was usually not abundant but generally found in all samples.

SHAVIOVIK RIVER MACROBENTHIC COMMUNITY

The macrobenthos of the Chaviovik River (Tables 4 and 5) was slightly different from the Sagavanirktok River macrobenthos.

Plecoptera

Within Plecoptera, Nemouridae was widely distributed and the most abundant. Chloroperlidae, although found in Sag and Canning Rivers during June, was absent from the collections in both June and August. Perlodidae was absent from the June collection but was found in the August set.

Ephemeroptera

Ephemeroptera was well represented in the Shaviovik River with both Baetidae and Heptagenidae widely distributed in both collection intervals. Ephemerellidae, previously collected from only the Lupine and Ivishak Rivers, was found at the lower two stations in June and August, but was absent from the upper two stations. Siphlonuridae was not found in this water course.

Trichoptera

Trichoptera was not found in the Shaviovik River.

Diptera

The five groups of Diptera were well represented in the Shaviovik River (Tables 4 and 5). During June, all stations except S-400 contained all five groups and only Brachycera was missing from the community at S-400. During August, the lower three stations generally harbored Chironomidae, Tipulidae, and Simuliidae. In addition to the above three families, station S-400 also harbored Ceratopogonidae and Brachycera, and was the only station on this river to do so in August.

Annelida

Annelida was found at all four stations during June but was collected from only the middle stations during August.

GALBRAITH AND NORA FED LAKES MACROBENTHIC COMMUNITY

Galbraith Lake and the two tundra lakes, Nora Fed 1 and Nora Fed 2, have significantly different morphology. Galbraith Lake is at an elevation of 802 m in the Brooks Range, is nearly 8 km long, about 1.5 km wide, a maximum of approximately 12 m deep, and is generally a good example of an oligotrophic lake. It has two clear water tributaries, an outlet, and generally has slightly turbid bluish water.

By contrast, the Nora Fed Lakes are located at an elevation of slightly more than 120 m in the Foothill Province, and are somewhat eliptical in shape, about 1.5 km across and no more than 3 m deep. They have no distinct inlet, an outlet that flows only at high water stage, and contain brownish tainted water with relatively high color and some turbidity.

Qualitative samples were collected from all three lakes during both June and August (Table 6). The biota found in these lakes were substantially different from those found in lotic habitats. Plecoptera, Ephemeroptera, and Diptera were found in the lakes and rivers but it can be generalized that these groups were less abundant and also showed less diversity in lake systems.

Trichoptera

Trichoptera was found in larger numbers, greater diversity than in streams, and in some habitats, dominated the community. Of the three families, Rhyacophilidae, Brachycentridae and Limnephilidae, only the latter was commonly found in all the lakes, although the August sample from Galbraith did not contain Limnephilidae. At times, large numbers of this family were observed crawling on the bottoms of small tundra pools and larger lakes. The next most abundant family was Brachycentridae, which was found in Nora Fed No. 2 during June and Galbraith during August. Rhyacophilidae was collected from only Nora Fed No. 1 during June.

Plecoptera and Ephemeroptera

Plecoptera and Ephemeroptera populations were substantially less abundant and showed less diversity in lakes than in river systems. Nemouridae was found in all lakes during both sampling periods and was the most important stonefly. Small numbers of Perlodidae were found only in Galbraith during both sampling periods. Only Baetidae (Ephemeroptera) was collected from lakes and then only in small numbers from Galbraith in June.

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TABLE 6. QUALITATIVE BIOLOGICAL DATA FROM 3 LAKE SYSTEMS IN THE SAGAVANIRKTOK RIVER STUDY, JUNE AND AUGUST 1969

ORGANISM Class Family	June			August		
	Galbraith Lake	Nora Fed #1	Nora Fed #2	Galbraith Lake	Nora Fed #1	Nora Fed #2
PLECOPTERA						
Perlodidae	X	X	-	X	-	-
Nemouridae	X	X	X	X	X	X
EPHEMEROPTERA						
Baetidae	X	-	-	-	-	-
DIPTERA						
Chironomidae	X	X	X	X	X	X
Tipulidae	X	X	-	X	-	-
Simuliidae	X	-	-	-	-	-
Ceratopogonidae	X	X	X	-	-	-
TRICHOPTERA						
Limnephilidae	X	X	X	-	X	X
Brachycentridae	-	-	X	X	-	-
Rhyacophilidae	-	X	-	-	-	-
ANNELIDA	X	X	X	-	-	-
AMPHIPODA	-	X	X	-	-	-
COLEOPTERA	X	X	X	-	-	-

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Diptera

Diptera were generally the most abundant organisms and were represented by four families. Chironomidae were ubiquitous regardless of season. Certatopogonidae were found in all the lakes but were absent from the August sample. Simuliidae was found in Galbraith and Nora Fed No. 1 Lakes only during June.

Annelida

Small numbers of annelida were consistently found in all lakes during June but the group was not found in August.

Amphipoda and Coleoptera

Amphipoda and Coleoptera were two groups that were found only in lakes. Amphipoda was abundant in the two tundra lakes during June but was not collected during August. The class Coleoptera was consistently found in all three lakes during June but had disappeared by the August sample interval. Miscellaneous other groups occasionally collected only in the lakes included Mollusca, Cladocera, and Copepoda.

LIST OF INVERTEBRATES COLLECTED FROM ALL LAKES AND STREAMS

The summary of invertebrates collected from all stations (Table 7) includes a wide variety of organisms. The list is dominated by four orders of insects: Plecoptera, Trichoptera, Ephemeroptera, and Diptera, which have been discussed earlier.

Miscellaneous Groups

Other numerically less important groups include: Nematoda, Turbellaria, Arachnida, Mollusca, Cladocera, Collembolla, Copepoda, Anostraca and Nematomorpha. Complete taxonomy of these later groups was impossible because of manpower and funding limitations. While the list is far from complete, it is a significant advancement of knowledge of aquatic biology of the lakes and rivers in Alaskan arctic regions. It is anticipated that subsequent investigations may discover a group which is relatively neglected at this time may become singularly important and that changes in this list will be made.

The miscellaneous groups listed in Table 7 generally are not important numerically or significant from a biomass point of view. However, since the objective of this study was to determine baseline conditions, some effort has been expended in this category.

Groups were encountered with varying frequency; i.e., Collembola were widely distributed while others such as Copepoda were rarely found. Some of the organisms were terrestrial forms that entered the aquatic sample by accident. For example, Arachnida and semi-aquatic Collemboda were incidentally collected. These may be important because organisms that accidently enter the water may comprise a large percentage of the total sample and may become

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TABLE 7. INVERTEBRATES COLLECTED FROM THE SAGAVANIRKTOK RIVER STUDY, 1969

- Plecoptera
  - Perlodidae
    - *Arcynopteryx sp.*
    - *Isogenus sp.*
    - *Isoperla sp.*
  - Chloroperlidae
    - *Alloperla sp.*
    - *Hastaperta sp.*
  - Nemouridae
    - *Nemoura sp.*
    - *Capnia sp.*
    - *Isocapnia sp.*
    - *Brachyptera sp.*
    - *Eucapnopsis sp.*

- Trichoptera
  - Limnephilidae
    - *Drusinus sp.*
    - *Limnephlius sp.*
    - *Radema sp.*
  - Brachycentridae
    - *Brachycentrus sp.*
  - Rhyacophilidae

- Ephemeroptera
  - Siphlonuridae
    - *Ameletus sp.*
    - *Siphlonurus sp.*
  - Heptageniidae
    - *Cinygmula sp.*
    - *Epeorus sp.*
    - *Iron*, *Ironopsis*
    - *Cinygma sp.* (1)
    - *Rithrogena sp.*
  - Baetidae
    - *Baetis sp.*
    - *Centroptilum sp.*
    - *Apobaetis sp.*
    - *Pseudoeleon sp.*
  - Ephemerellidae
    - *Ephemerella sp.*
    - *Metretopus sp.*

- Diptera
  - Chironomidae
  - Chironominae
    - *Chironomus sp.*
    - *Stictochironomus sp.*
    - *Tanytarus sp.*
  - Orthocladiinae
    - *Brillia sp.*
    - *Corynoneura sp.*
    - *Cricotopus sp.*
    - *Spaniotoma sp.*
    - *Nanocladius sp.*
    - *Orthocladius sp.*
    - *Psectrocladius sp.*
    - *Smittia sp.*
    - *Trichochladius sp.*
  - Diamesinae
    - *Diamesa sp.*
    - *Prodiamesa sp.*
  - Tanypodinae
    - *Procladius sp.*
    - *Pentaneura sp.*

- Annelida

- Miscellaneous Diptera
  - Simuliidae
  - Tipulidae
  - Tabanidae
  - Empididae
  - Ceratopogonidae
  - Psychodidae
  - Dixidae
  - Culicidae
  - Sciaridae
  - Brachycera
  - Coleoptera
  - Dytiscidae
  - Hydraenidae
  - Carabidae
  - Staphylinidae
  - Acari
  - Nematoda
  - Turbellaria
  - Arachnida
  - Mollusca
  - Cladocera
  - Copepods
  - Anostraca
  - Nematomorpha

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important food items to fish. Schallock (1965a) recorded Alaskan grayling feeding extensively on terrestrial insects (Pentatomidae) that had fallen into the water.

Several members of this list were widely distributed with a few organisms present at most stations but not at others. Acari, several families of Diptera, and free living Nematoda, are the notables in this instance. Members of several families of Coleoptera (Dytiscidae, Hydraenidae, Haliplidae, Carabidae, and Staphylinidae) were collected from both streams and lakes with the latter environemnt having more diversified Coleoptera fauna.

Two other groups, Amphipoda and Trichoptera, were found primarily in lakes although occasional Trichoptera were collected in the upper Sagavanirktok River. Cladocera and Copepoda were closely associated with Galbraith Lake and the outlet stream that transports some of these lake-frequenting organisms into the Atigun River.

BACILLARIOPHYCEAE (DIATOMS) FROM RIVERS IN THE SAGAVANIRKTOK RIVER STUDY

Diatoms that have been collected and identified from aquatic environments from the Sag River and Alaskan North Slope in the vicinity of the Canning River are presented in Table 8. These determinations were made by Dr. Ruth Patrick and affiliated taxonomists of the Academy of Natural Sciences.

SANITARY MICROBIOLOGY FROM RIVERS

Sanitary microbiology consisted of identifying the baseline levels of total coliform bacteria that existed in the Sag River, its tributaries and the Canning and Shaviovik Rivers. These bacteria were to be used as indicators to predict the suitability of water for particular uses; i.e., presence of significant numbers of these organisms would indicate a strong possibility that pathogenic organisms would also be present and would then preclude use of this water without treatment for certain purposes such as drinking.

A total of 81 samples were collected from 27 stations on the Sag River, its tributaries, and the Canning and Shaviovik Rivers. Analyses of these samples revealed that low numbers (less than 5/100 ml) of total coliform bacteria were found in virtually all of the rivers. Only samples from the station on the Ivishak River and the stations immediately above and below the Sagavanirktok River confluence with the Ivishak contained substantial numbers of total coliform bacteria (as many as 227). During the entire study, these were the only samples having counts of this magnitude. Samples were subsequently taken from the same vicinity but these results were then similar to results from other areas. Further elaboration on impact of resource development on water quality in the Sag River may be obtained from Schallock, 1976. Identification of some total coliform bacteria has been done by Kaska, 1976.

Based on these results, it has been concluded that the waters of the Sagavanirktok River, its tributaries, and the Canning and Shaviovik Rivers were generally acceptable from sanitary bacteriology aspects. Therefore, at

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TABLE 8. DIATOMS IDENTIFIED FROM ALASKAN NORTH SLOPE. ALASKA SPECIES LIST

- Anchnanthes clevei v. rostrata Hust.
  - elliptica v. pungens Cl.-Eul.
  - exiqua v. heterovalvata Krass.
  - flexella (Kutz.) Brun.
  - fragilaroides Boye Peterson
  - lacunicola Patr. and Freese
  - laceolata (Breb.) Grun.
  - lanceolata v. dubia Grun.
  - lemmermanni Hust.
  - linearis (W. Sm.) Grun.
  - minutissima Kutz.
  - pinnata Hust.
  - subhudsonis v. Kraeusellii Choln.
  - thienemanni Hust.
  - sp. 1. (AL)

- Actinoptychus undulata (Bail.) Ralfs.

- Amphipleura pellucida (Kutz.) Kutz.

- Amphora alaskana Patr. and Freese
  - cymbelloides Grun
  - ovalis (Kutz.) Kutz.
  - ovalis v. pediculus (Kutz.) V.H.
  - submontana Hust.

- Anomoeonesis serians (Breb. ex Kutz.) Cl.
  - serians v. thermalis Grun.
  - vitrea (Grun.) Ross
  - zelensis (Grun.) Cl.

- Astrionella formosa Hassal.

- Caloneiss bacillum (Grun.) Cl.
  - fasciata (Larerst.) Cl.
  - schumanniana (Grun.) Cl.
  - silicula v. truncatula (Grun.) Cl.

- Ceratoneiss arcus v. linearis Holmboe
  - arcus v. recta Cl.

- Cocconeiss disculus (Schum.) Cl.
  - placentula v. euglypta (Ehr.) Cl.

- Coscinodiscus lineatus Ehr.

- Cyclotella antigua W. Sm.
  - comensis Grun.
  - compta (Ehr.) Kutz.
  - kuetzingiana Thw.
  - meneghiniana Kutz.
  - ocellata Pant.
  - pseudostelligera Hust.

- Cymatopleura solea (Breb. and Godeey) W. Sm.

- Cymbella affinis Kutz.
  - amphicephala Naeg.
  - broenlundensis Foged
  - cuspidata Kutz.
  - lapponica Grun.
  - latens Krasske
  - microcephala Grun.
  - naviculiformis Auersw. ex. Heib.
  - obtusa Greg.
  - parva (W. Sm.) Cl.
  - perpusilla A. Cl.
  - semigibbosa Patr. & Freese
  - similis Krasske
  - sinuata Greg.
  - stauroneiformis Lagerst.
  - tumida (Breb.) V. H.
  - tumidula Grun.
  - turgida Greg.
  - turgida v. barrwiana Patr. and Freese
  - turgidula Grun.
  - ventricosa Ag.
  - ventricosa v. groenlandica Foged
  - sp. 1 (AL)
  - sp. 2 (AL)

- Denticula tenuis Kutz.

- Diatoma hiemale (Roth) Heib.
  - hiemale v. mesodon (Ehr.) Grun.
  - tenue v. elongatum Lyngb.

- Diatomella balfourina Grev.

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TABLE 8 (continued)

- Didymosphenia geminata (Lyngbye) M. Schmidt

- Diploneis elliptica (Kutz.) Cl.
  - oblongella (Naeg. ex Kutz.) Ross
  - oculata (Breb.) Cl.
  - puella (Schum.) Cl.

- Epithemia sorex Kutz.
  - turgida (Ehr.) Kutz.
  - zebra (Ehr.) Kutz.

- Eunotia curvata (Kutz.) Lagerst.
  - major (W. Sm.) Rabh.
  - paludosa Grun.
  - pectinalis (O. F. Muell.) Rabh.
  - pectinalis v. minor (Kutz.) Grun.
  - praerupta Ehr.
  - praerupta v. inflata Grun.
  - speudopectinalis Hust.
  - septentrionalis Østr.
  - tenella (Grun.) Hust.
  - triodon Ehr.

- Fragilaria bicapitata A. Mayer
  - construens v. venter (Ehr.) Hust.
  - crotonensis Kitton
  - leptostauron (Eph.) Hust.
  - pinnata Ehr.
  - pinnata var. 1 (AL)
  - undata v. quadrata Hust.
  - vaucheriae (Kutz.) Peters.

- Frustulia vulgaris (Thw.) DeT.

- Gomphonema acuminatum Ehr.
  - angustatum v. producta Grun.
  - constrictum v. capitatum (Ehr.) V. H.
  - gracile (Ehr.) V. H.
  - intricatum v. minor Skv.
  - lagerheimii A. Cl.
  - longiceps v. subclavatua Grun.
  - longiceps v. montana fo. minuta Skv.
  - olivaceoides v. lanceolata Manguin
  - parvulum Kutz.

- Gyrosigma attenuatum (Kutz) Rabenh.
  - spencerii (W. Sm.) Cl.

- Hannaea arcus (Ehr.) Patr.
  - arcus v. amphioxys (Rabh.) Patr.

- Hantzschia amphioxys (Ehr.) Grun.

- Melosira distans (Ehr.) Kutz.
  - italica (Ehr.) Kutz.
  - italica v. tenuissima (Grun.) O. Mull.
  - granulata (Ehr.) Ralfs.
  - sulcata fo. radiata Grun.

- Meridion circulare (Grev.) Ag.

- Navicula anglica Ralfs.
  - bacilliformis Grun.
  - bacillum Ehr.
  - capitata Ehr.
  - capitata v. hungarica (Grun.) Ross
  - cincta (Ehr.) Ralfs.
  - citrus Krasske
  - clementis Grun.
  - cocconeiformis Greg. ex Greg.
  - comoides (Ag?) Perag.
  - contenta Grun.
  - contenta fo. biceps (Arn.) V. H.
  - cryptocephala Kutz.
  - cryptocephala v. veneta (Kutz.) Hust.
  - crucicula v. alaskana Patr. and Freese
  - cuspidata (Kutz.) Kutz.
  - decussis Ø str.
  - disjuncta Hust.
  - elginensis (Greg.) Ralfs.
  - explanata Hust.
  - fritschii Lund.
  - gibulla Cl.
  - gottlandica Grun.
  - gregaria Donk.
  - hungarica v. artica Patr. and Freese
  - importuna Hust.
  - jarenfeltii Hust.
  - lacuna Patr. and Freese
  - lagerstedtii Cl.
  - lanceolata (Ag.) Kutz.

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lapidosa Krasske
menisculus Schumann
minima Grun.
minima v. atomoides (Grun.) Cl.
minuscla Grun.
muralis Grun.
mutica Kutz.
mutica v. cohnii (Hilse) Grun.
obsidialis Hust.
palaearctica Hust.
paucivisitata Patr.
pelliculosa (Breb. ex Kutz.)
protracta (Grun.)
pseudoscutiformis Hust.
pseudosiliculoides Foged
pupla Kutz.
pupla v. mutata (Krasske) Hust.
pupula v. rectangularis (Greg.) Grun.
pupula v. rostarata Hust.
pygmaea Kutz.
radiosa Kutz.
rhyncocephala Kutz.
rotaeana (Rabh.) Grun.
salinarum Grun.
salinarum v. intermedia (Grun.) Cl.
salsa Patr. and Freese
seminulum Grun.
soehrensis v. septentrionalis Hust.
stromii Hust.
subhamulata Grun.
tripunctata v. schizonemoides (V. H.) Patr.
ventralis Krasske
viridula (Kutz.) Kutz.
viridula v. linearis Hust.
wigginsiana Patr. & Freese
sp. 1 (AL)
sp. 3 (AL)

Neidium affine (Ehr.) Pfitz.
alpinum Hust.
apiculatum Reim.
binode (Ehr.) Hust.
bisulcatum (Lagerst.) Cl.
bisulcatum v. nipponicum skv.
iridis (Ehr.) Cl.
sp. 1 (AL)

Nitzschia amphibia Grun.
bacata Hust.
capitellata Hust
clausii Hantz.
confinis Hust.
diserta Hust.
dissipata (Kutz.) Grun.
filiformis (W. Sm.) Hust.
fonticola Grun.
frustulum (Kutz.) Grun.
frustulum v. perminuta Grun.
gracilis Hantz.
grandersheimiensis Krasske ex Hust.
hungarica Grun.
kuetzingiana v. exilis Grun.
lacuna Patr. and Freese
linearis (Ag.) W. Sm.
palea (Kutz.) W. Sm.
sigma (Kutz.) W. Sm.
sp. 1 (AL)
subtilis Kutz.

Oestrupia zachariasi (Reich.) Hust.

Opephora martyii Herib.

Pinnularia abauiensis v. subundulata (A. Mayer ex Hust.) Patr.
anceps v. americana Reim.
balfouriana Grun.
biceps Greg.
borealis Ehr.
divergentissma (Grun.) Cl.
gibba (Ehr.) W. Sm.
gracilliama Greg.
intermedia (Lagerst.) Cl.
interrupta W. Sm.
interrupta fo. minutissma Hust.
major (Kutz.) Cl.
mesolepta (Ehr.) W. Sm.
microstauron (Ehr.) Cl.
molaris (Grun.) Cl.
obscura Krasske
parva var. minut Østr.

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TABLE 8 (continued)

sublinearis (Grun.) Cl.
  tenuiraphe Patr. and Freese

Pseudo-nitzschia sicula v.
  migrans Cl.

Rhopalodia gibba (Ehr.) O. Mull.

Rhaphoeis amphiceros Ehr.

Rhoicosphenia curvata (Kutz.)
  Grun.

Stauroneis anceps Ehr.
  anceps fo. gracilis Rabh.
  attenuirostris Patr. and Freese
  barrowiana Patr. and Freese
  barrowiana Patr. and Freese
  ignorata Hust.
  lapponica Hust.
  parvula Janisch
  smithii Grun.

Stephanodiscus astraea (Ehr.) Grun.

Surirella angusta Kutz.
  margaretiana Patr. and Freese
  ovata Kutz.
  ovata v. pinnata (W. Sm.)
  tenera v. nervosa A. Mayer
  terryi v. arctica Patr.
    and Freese

This list contains 44 genera and numerous species and variations. Diatoms were ubiquitously distributed, at times luxuriantly abundant in some area, while scarcely detectable in others. With this wide distribution and long species list, diatoms are well represented in arctic aquatic environments.

the time of the study, the waters of these drainages were suitable for the highest human uses, which are classified "A" according to the State of Alaska Water Quality Standards.

PISCIFAUNA

Sagavanirktok River drainages and adjacent watersheds such as Canning and Shaviovik Rivers, contain populations of grayling, arctic char, lake trout and pike. All are desirable sport fish and each has a unique and pleasing flavor. Whitefish are also found in these watersheds and are good eating although not readily obtained by anglers. Nine-spine sticklback, slimy sculpin, and ling cod are of little direct importance to either the commercial or sport fishing industry. They may, however, be important in the intra-specific relationships such as predators or prey species and thereby affect the more important sport or commercial fishes.

The piscifauna data presented in Tables 9 and 10 were collected at stations where physical, chemical and other biological data were collected. The sampling schedule was based primarily on sampling macrobenthic organisms, thereby preventing the collection of additional data at these and other stations.

The common names and scientific nams of fishes that were collected or observed in the Saganirktok River and adjacent drainages are listed in Table 11.

Grayling

Grayling, Thymllus arcticus, was observed in large lakes, streams and rivers from the Canning River system west to the Sagavanirktok River drainages. These fish did not appear to be uniformly distributed along flowing water systems but rather appeared to concentrate in specific reaches of a river and even furthermore congregated in deep holes. The number of adult and subadult grayling found in deep holes and specific reaches of rivers appeared low when compared to interior Alaskan rivers such as the Chatanika.

Except for short periods of increased turbidity due to spates, grayling were generally available to anglers throughout the open water period from spring breakup to fall freezeup. Creek census and angler interviews revealed that fishermen catches averaged near 30 cm (Tables 9 and 10). Interior Alaskan fish this size are generally mature and part of the spawning segment of the population (Schallock, 1965a). However, the virtual absence of young-of-the-year and 1+ and 2+ age groups suggests that the adults may spawn only in specific reaches or in other streams. Spawning in one stream and rearing of young-of-the-year in that stream before migration to another stream has been recorded from interior streams by Schallock (1965b).

Suggested low population levels, average large size of fish appearing in angler creels, and limited numbers of immature fish are often characteristic of populations that have not been heavily harvested and have accumulated numbers of large fish. These large fish are easy to harvest because of tendencies to congregate in limited areas where anglers readily catch them.

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TABLE 9. PISCIFAUNA DATA. SAGAVANIRKTOK RIVER BASIN

Location	Date	# Hours in Set (125' Experimental Monofilament Gill Net)	Fish	Size (cm-Fork Length)	Sex
Galbraith Lake					
North Inles Area	27 June 1969	13 hours	Round Whitefish	15.3	U*
			Round Whitefish	15.7	U
			Round Whitefish	16.0	U
			Round Whitefish	23.7	M*
			Lake Trout	31.7	U
			Lake Trout	37.8	U
			Lake Trout	42.3	U
Galbraith Lake					
South Inlet Area	27 June 1969	5 hours	Grayling	34.2	M
Galbriath Lake	22 Aug. 1969	14 hours	1 Round Whitefish	34.6	F*
			2	33.0	F
			3	28.0	M
			4	27.2	M
			5	23.4	M
			6	22.4	M
			7	15.7	U
			8	15.0	U
			Grayling	9.9	-
			1 Lake Trout	59.0	M
			2	77.5	M
			3	47.1	U
			Arctic Char	41.1	F

* These symbols are:
U - Sex unknown
M - Male
F - Female

TABLE 10. PISCIFAUNA ANGLING AND OBSERVATIONS

Location	Date	# Hours In Sample	Fish	Size	Sex	Remarks
Atigun Creek (near Galbraith Lake	21 Aug. 69	Angler obs.	Grayling	35-40 cm	--	30-40 observed in one pool
Lupine River	21 Aug. 69	Rod & line	Arctic Char	59.2	F	Gravid
		(1 hr + 20 min)	2 Arctic Char (released)	30-40 cm	U	
		(1 hr + 20 min)	Grayling (released)	25-30 cm		
Ivishak River	14 Aug. 1969	Rod & line 1½ hr	Arctic Char	40-50 cm	2M	Taken in one pool by two anglers
Franklin Bluff Area	Numerous Occasions	Angling	Arctic Char & Grayling			Numerous sightings of aircraft landing in this area for angling
Sagavanirktok Mouth	June and July	Rod & line	Arctic Char			Angler reports of good catches of char in the period
Canning River	June and August	Rod & line	Grayling	35-40 cm		Several grayling captured and released. Anglers reported char but none were positively identified or collected.
Kaderoshilik River	August	Observed	Stickleback and Sculpin			Both these fish were collected in this drainage.

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TABLE 10 (continued)

Location	Date	# Hours In Sample	Fish	Size	Sex	Remarks
Kuparuk River	June, July August	--	--			Anglers report good catches of large grayling in clear water.
Nora Fed Lakes (15 mi. north Sagwon	June	Dip Net	Stickleback			Found in small numbers.
Shaviovik River Juniper Creek Area	June	Observed		30-38 cm		Many fish in the 30-38 cm range were seen from the air but none were collected or closely observed.
Unnamed Tundra Lakes	August	Observed		30-60 cm		Several fish from the 30-cm range were observed swimming in the lake.

TABLE 11. PISCIFAUNA. SAGAVANIRKTOK RIVER AND ADJACENT DRAINAGES

Common Name	Scientific Name
Grayling	*Thymallus arcticus*
Lake Trout	*Salvelinus namaycush*
Arctic Char	*Salvelinus alpinus*
Pike	*Esox lucius*
Round Whitefish	*Prosopium cylindraceum*
Ling Cod	*Lota lota*
Slimy Sculpin	*Cottus cognatus*
Nine Spine Stickleback	*Pungitus pungitis*

Extensive harvesting of this segment of the population may drastically reduce the spawning population and reproductive potential. The tendency of adults to congregate in specific reaches of rivers, spawning in specific areas and the utilization of segments of systems for rearing of young-of-the-year causes concern that some streams or specific reaches of a stream are critical to fish populations and therefore may need protection by regulation.

Arctic Char

Arctic char, *Salvelinus alpinus*, are widely distributed in Alaska's North Slope and are usually found in larger drainages such as the Colville, Sagavanirktok and Canning Rivers. Adult arctic char exhibit strong upstream migratory movements during the summer and early autumn. Char are available to anglers at the mouth of the Sagavanirktok River in June but angler success in that area diminishes in July when the fish reach the Foothill Province area and become available to anglers in deep holes found in the Sagavanirktok River and some of its tributaries in this general area. Ivishak and Lupine Rivers harbored char caught by anglers and investigators. Char exhibiting definite upstream migration behavior were observed at Sagwon in mid-Ausut. The fish apparently are distributed throughout the Sagavanirktok River drainage in the Foothill Province and some are still moving upstream in mid-August.

Char were also collected by test net in Galbraith Lake. It is not known whether the fish that were collected had migrated up the Sagavanirktok River and negotiated the Atigun canyon by mid-August or whether the fish were a member of a resident population of char that frequent the waters of Galbraith Lake throughout the year. McCart and Craig (1971) feel that char in Galbraith and other nearby lakes are separate non-migratory populations while those fish that were found in the Sagavanirktok River, Ivishak, Ribdon, Accomplishment and Section Creeks are anadromous.

Arctic char too are vulnerable to anglers. The most difficult element in catching char is finding the fish but once this obstacle is overcome, angler success is high. At times angling success may be limited by turbid water but in general the water is clear during the summer.

Although data are limited, the char of the Canning River apparently adhere to similar time tables in their migration up the Canning River. It is conceivable that the populations of different streams mix while in the marine or estuarine environment. Apparently, the char utilize specific areas of streams for spawning and for rearing. If this is true, it would be exceptionally dangerous to over-exploit or harvest the fish that frequent a spawning area or nursery stream. Young char, approximately 10 cm long, have been collected from the Sagavanirktok River indicating reproduction in this system.

Lake Trout

Lake trout, Salvelinus namaycush, are generally found in the deeper lakes such as Galbraith, Itkillik and Elusive but not in shallow tundra lakes on the Coastal Plain. Limited gill net sampling in Galbraith Lake revealed a population with a distribution skewed toward older individuals, also suggesting that this lake harbored a relatively unharvested population.

Pike

Northern pike, Esox lucius, are usually found in the deepest of the brownish water tundra lakes located in the Coastal Plain Province. These lakes are of thermokarst origin and usually are less than 3 m deep which, when combined with environmental features may cause, along with other problems, dissolved oxygen depression during winter. Some pike populations in the Coastal Plain Province are subjected to lethal conditions, since pike skeletons were observed on an unnamed lake beach while the ice was melting from the lakes.

Whitefish

Whitefish, Prosopium cylindraceum, were found in both lakes and streams. These fish are not directly important as a sport fish but are utilized in a commercial fishery on the Colville River. However, it is doubtful that this fish is abundant enough in the Sagavanirktok River drainages to support a commercial fishery. This species, however, may be an important food fish for other predatory fish. They may also compete for food organisms.

Management Implications

Specific aspects of fish behavior and life history when combined with certain features of the arctic environment are causing some concern in fishery management agencies. Each behavior trait or environmental factor may be insignificant when considered individually but when all the different facets are collectively evaluated, the total picture may be considerably different and more significant than anticipated.

One of these features of the arctic aquatic environment is limited discharge during winter. This characteristic has a direct impact on lentic and lotic systems. Lakes and stream courses may have small amounts of water circulating through the system. As a result, many lakes and some reaches of rivers may be considered closed systems, at least during winter.

Thus, fish such as grayling, char, lake trout, pike and whitefish that inhabit lakes or certain reaches of rivers may be vulnerable to any pollutant until it is degraded or dissipated. This situation is different from and more prolonged than the summer scence when pollutants are more readily diluted, more rapidly degraded or in some instances transported away from a specific area by a stream system. As a result, lower concentrations or small disturbances may have deleterious effects. In instances where an effluent, such as sewage waste, is continually added to a lake, any effect may be accumulative and much more insidious and less obvious than death.

Another feature of the arctic aquatic environment is the severely depressed dissolved oxygen concentrations that have been found in some water systems. This factor and the low discharge characteristic have been discussed as the areas in which problems will most likely develop in streams. Small amounts of water with low dissolved oxygen concentrations suggest that small amounts of effluent with oxygen demand or with any toxic component may be harmful to the indigenous biota. Although these organisms frequent streams, the biota often are confined to specific reaches of the system because of reduced discharge and the ice and snow cover that prevails over virtually all stream surfaces and often extends from bank to bank and to, or nearly to, the stream bottom. In addition to confinement, the organisms may be stressed in the natural situation by low dissolved oxygen (as low as 1.1 mg/l) as well as by other water quality parameters that change substantially during winter.

The dissolved oxygen and the surface discharge factors, when combined with the tendencies of fish to inhabit specific reaches of rivers for certain segments of their life cycle, cause an environmental and biological setting to which small changes or additions have high potential for significant harm to fishery populations.

INTERRELATIONSHIPS BETWEEN AQUATIC BIOTA AND PHYSICAL AND CHEMICAL ENVIRONMENT

The interaction between the physical and chemical environment and the biological communities is an extremely complex relationship. The number of factors that contribute to the total environmental scene is large and the number of combinations in which the different factors can interrelate is virtually infinite.

The primary objective of this study was to establish baseline conditions and, secondly, to discuss some of the factors that may affect the numbers and distribution of the indigenous aquatic organisms. This cause-effect discussion can only be superficial because of the complexity of the topic and because of the primary scope of the project. The approach that will be used is how the production of an aquatic biological community, group of organisms, or in some instances a specific organism, may be affected by a single of collection of physical and/or chemical parameter(s).

Those biological groups included in this discussion are Bacilliariophyceae (diatoms), Plecoptera, Ephemeroptera, Trichoptera, Diptera and the fishes. The physical and chemical parameters to b addressed are water temperature, surface discharge, dissolved oxygen, pH, specific conductance, nitrogen forms, phosphate forms and silica.

Primary productivity in these arctic stream systems is achieved by Bacillariophyceae and by filamentous algae in restricted reaches of some systems. Several factors affect the annual production of this group. Certainly the long winter season with accompanying low water temperatures, low discharge, low light incidence, and ice and snow cover restrict the areas and the time in which production can occur. During the summer, primary production, while not limited by the same factors that are present during the winter, is limited by some factor(s). Among these factors are turbidity, color and fixed suspended solids which combine to reduce light penetration during spring breakup and summer spates. During the intervals of summer when the water is clear, other factors such as water temperature and light intensity may be less than optimal and while photosynthesis is occurring it may not be proceeding at the maximum rate. Other factors such as the availability of the nitrogen forms, phosphate, silica, and micronutrients may limit production.

The second group of organisms to be discussed is the benthic community. This assemblage is comprised almost entirely of aquatic insects although other non-insects are commonly and rightfully placed in this category. This diverse group includes organisms with different life histories and different requirements. For these reasons, it is difficult to make generalizations that cover all situations. However, some general statements will be made which future studies will substantiate or in some instances disprove.

In the previous section, it is noted that primary productivity is generally restricted to diatoms that are generally widely distributed but not abundant. This paucity of primary productivity and the small amount of allochthonos material that is added to the water is probably the principal reason for the recorded numbers and the observed biomass of the macrobenthic community. Those organisms that derive energy from either allochthonous sources or from grazing on the primary producers may be found in low numbers. Consequently, the carnivorous invertebrates would also be present in low numbers.

Water temperature and temperature patterns may affect the kinds, numbers, and distribution of macroinvertebrates. The long winter period with water temperatures near 0°C may in itself be limiting. The relatively short summer with higher, but still considerably cooler water temperatures than those found in Interior Alaska and in more temperate climates may also be limiting. Furthermore, in the Sag River, the warmest water temperatures were usually found in the Foothill Province. Thus, the rate of development probably would proceed at the fastest rate in this reach of the river.

Several other factors that occur during winter may affect the diversity, numbers and distribution of macroinvertebrates. Winter surface discharge is only a small fraction of the discharge may cease. Cessation of flow combined with other environmental features has several ramifications. Reaches of the river may be dewatered; dissolved oxygen concentrations may be severely depressed; pH may become more acidic; and concentrations of many cations and anions generally increase to concentrations much higher than those recorded during summer. Any one or combination of these factors may adversely affect an organism or group of organisms and thereby alter the entire community.

Several fish populations have been identified in the Sag and other river systems on the North Slope. The generalization made here will apply to the anadromous or migratory fish such as arctic char, arctic grayling and the round whitefish.

Several factors already discussed in the primary productivity and macrobenthic sections also may affect the diversity, numbers and distribution of life stages of fishes. Surface discharge is probably one of the most significant factors affecting the winter distribution, and conceivably the summer distribution, of the young-of-the-year, immature, and adult stages of populations of fish. Tendencies to congregate near spring areas in rivers have been observed. Thus, specific reaches of systems can be extremely important to the survival of that population. However, both grayling and char are known to overwinter in pool areas of the Sag River in the Coastal Province although no spring areas have been identified in these reaches of the river.

Other conditions during winter may limit fish populations. Dissolved oxygen has been shown to be severely depressed in some reaches of the Sag River. Concentrations as low as 1.1 mg/l have been documented and have high potential for limiting populations. High concentrations of cations and anions may also contribute to the critical winter season that is felt by many fishery and aquatic biologists to be the critical period for aquatic populations.

The distribution of different developmental stages of fish may be influenced by the abundance and diversity of the macrobenthic community which generally increases when proceeding south from the Coastal Province through the Foothill Province and then into the Mountain Province. Availability of food and the preference for certain food items can be extremely important factors during the summer when the majority of growth is found in fishes, especially in the young-of-the-year and immature stages.

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SECTION VI

PHYSICAL AND CHEMICAL PARAMETERS

SAGAVANIRKTOK RIVER

Occasional efforts have been made to describe the physical and chemical properties of flowing waters in arctic Alaska. Arnborg, et al. (1966, 1967) discuss the discharge and suspended sediment load in the Colville River. Brown et al. (1962) describe mineral content of small seeps and streams and relate these characteristics to geological features of the area. Other information has been limited to casual reference made to individual properties of arctic stream systems by investigators primarily interested in other disciplines. No concentrated effort has been made to study the physical and chemical properties of an arctic river. It is the intent of this segment of the study to provide information to partially fill this need.

Water Temperature

Water temperature at any given time is the net effect of many factors operating simultaneously to warm and cool the water mass. Initially, the temperature is established by the primary water source such as snow-melt, rain, and subterranean springs. Once in the stream system, the usually cool headwaters are warmed by air, sun or conduction from the ground (Haynes, 1970). However, it is doubtful that conduction has an appreciable warming effect on arctic rivers; it is more probable that ground temperatures have a cooling effect, particularly during the summer. Downstream warming has been described by Schmitz and Volkert (1959) and Eckel (1953) as roughly proportional to the logarithm of the distance from the source. Warming may be retarded by increased discharge (Dorris et al., 1963), by snow melt-water (Sheridan, 1961), and evaporation. At times, auf eis is an important contributor to melt-water and to cooling.

Love (1965) states that air temperatures directly influence both seasonal and daily water temperatures. Ricker (1935) reports that solar radiation is more important than air temperatures to warming water during the summer but a minimal influence during the winter when solar radiation is virtually absent for extended periods of time and when ice and snow act as insulation slowing the penetration of cold from ambient air patterns.

These and other interrelated factors cause two characteristic seasonal extremes in the annual temperature regime of arctic rivers. The winter regime, which is the longest, most dominant and the least studied, begins in September, ends in April or May, and is characterized by relatively stable water temperatures hovering near or at 0°C (32°F). Concurrent conditions with these temperatures are virtual total ice and snow cover with large accumulated masses of auf eis in some areas and substantially smaller discharges that sometimes flow through and between strata of ice or in the alluvium. Other features are low incident or absent solar radiation for extended periods of time, substantial increases of some and decreases in other dissolved substances. The other extreme is found during the warm season and includes comparatively warm air temperatures and long periods of low incident solar radiation, rapidly fluctuating discharge, and somewhat lower concentrations of most dissolved substances.

The water temperatures in the Sagavanirktok River basin ranged from 3.9°C (39.0°F) to 12°C (53.6°F) in the June sample period and from 1.3°C (34.3°F) to 6.7°C (44.8°F) in the August sampling interval. These data reveal a general increase in water temperatures from the Mountain Province (S-1300) to the Foothills Province near Sagwon (S-700) about 112 km (70 mi.) inland, but a decrease from this area toward the coast. This is probably due to the dense fog banks commonly found along the arctic coast. Sater et al. (1971) report that coastal areas experience fog more than 100 days per year, most frequently in summer. It should be noted that the above temperature data were collected on clear days when flying was not impeded by these fog banks. Therefore, the reach of the river traversing the Coastal Plain Province is probably even cooler when the area is covered by fog.

Air temperature data collected during June show drastically higher temperatures than those collected in August. The water temperatures reflect the higher June air temperatures although air temperatures are rapidly responsive to short-term localized and transitory conditions such as cloud cover.

Dissolved Oxygen

Dissolved oxygen (D.O.) concentrations ranged from 1.1 mg/l during April to 13.3 mg/l during August. The drastically depleted D.O. concentrations (8 percent saturation) found during April (1.1 mg/l) are characteristic of a winter phenomenon recently described in several Alaskan rivers (Schallock and Lotspeich, 1974). This severe depression of dissolved oxygen is usually most critical in the lower reaches of rivers and was documented in small and medium sized rivers such is the Chatanika or Chena and also in large rivers such as the Yukon where winter dissolved oxygen concentrations ranged from 10.5 mg/l at the Canadian Border to 1.1 mg/l near the mouth. Dissolved oxygen was reasonably higher in August (12.0 to 13.3 mg/l) than in June (9.9 to 12.6 mg/l) when water temperatures were higher. Dissolved oxygen concentrations during summer were consistently high.

Surface Discharge

Patterns of surface discharge and suspended sediment load of the Colville River have been published by Arnborg et al. (1966, 1967). As much as 43 percent of the annual runoff and most of the accumulated ice and snow may be discharged in a three-week interval at "breakup". He further states that discharge ceases during winter and generally reaches a maximum during breakup. In the Sagavanirktok River, it is accepted that breakup is usually the maximum discharge but some controversy exists about whether discharge ceases entirely during the winter because open water has been observed flowing in specific reaches of the river such as the confluence of the Lupine River and Sagavanirktok River. U.S. Geological Survey personnel took discharge measurements in April at station S-700 located about 32 km (20 mi.) downstream from the mouth of the Lupine River but were not able to detect a measurable discharge. One explanation is that the river flow may be contained in the alluvium in certain reaches of the river.

Discharge measurements from 8 stations, collected by U.S. Geological Survey in a 6-day interval in August and presented in Table 12, permit general comparison of some tributaries to the Sagavanirktok River. It should be noted that seasonal rainstorms cause temporary, rapid and sometimes large variation in discharge. This characteristic is caused by localized rain storms, underlying continuous permafrost, limited thaw zones beneath water collection areas, low air temperatures and limited transpiration--all combining to cause a large percentage of summer precipitation to be transported as runoff rather than recharged into the groundwater system.

TABLE 12. DISCHARGE MEASUREMENTS FOR STATIONS. SAGAVANIRKTOK RIVER BASIN

Station	Date	Discharge, cfs
A-200	08/21/69	111
Gal. Out.	08/21/69	39
F-100	08/19/69	182
S-1300	08/19/69	203
R-100	08/19/69	788
L-100	08/21/69	226
S-800	08/21/69	1990
I-100	08/17/69	2520

Tributaries contribute a wide range of volumes of water to the Sagavanirktok River mainstem. The largest tributary, from a volume point of view, is the Ivishak. Although this is a single measurement, it is probably the most important single tributary. The next largest volume is contributed by the Ribdon River. Galbraith Lake is a relatively small source but is important to the flow in Atigun Canyon. Since all measurements were made during August; it may be expected that substantially larger volumes would be found in June and July but smaller volumes in winter.

Turbidity

Turbidity is caused by a variety of suspended inorganic and organic materials such as clay, silt, plankton, or other microscopic organisms. In most instances, turbidity is caused by a combination of these materials with the importance of any one changing from time to time and place to place. Generally, turbidity can be related to siltaceous material mixed with some organic material.

Data from stations in the Sagavanirktok River basin is presented in Table 13. Turbidity ranged from 64 Jackson Turbidity Units (JTU) in June 1969 to the low of 4.3 JTU in August. The post-breakup data collected in June 1969 ranged from 21 to 64 and were generally significantly higher than the August data. Arnborg (1966) reports that 60 percent of the total annual suspended material was transported during the first 20 days of June, during breakup in the Colville River. The samples collected from S-700 and S-800 during the April ice-covered period showed unexpected high turbidity. It was expected that turbidity of these stations would be similar to those recorded from S-200 during the same interval because discharges and water velocities during winter are much lower than those of June and August and direct correlations have been made between suspended materials and both water velocity and discharge. Also, no runoff is occuring at this time. In general, turbidity data collected during summer can be expected to be higher than data collected during winter. It is possible that industry activities affected this and other parameters since contractors operating out of Sagwon were utilizing the Sagavanirktok River as a water source at this time.

TABLE 13. TURBIDITY DATA FOR SAG RIVER BASIN

Station	Date	Turbidity JTU	Date	Turbidity JTU	Date	Turbidity JTU
S-1300	06/11/69	35	08/19/69	4.3	----	----
S-1200	06/12/69	43	08/19/69	9.7	----	----
S-1100	06/12/69	43	08/19/69	6.7	----	----
S-1000	06/12/69	49	08/20/69	12.0	----	----
S-900	06/12/69	49	08/21/69	11.5	04/22/70	75
S-800	06/12/69	58	08/14/69	16.5	04/22/70	120
S-700	06/24/69	37	08/14/69	13.2	----	----
S-600	06/24/69	47	08/14/69	12.2	----	----
S-500	06/13/69	57	08/14/69	14.5	----	----
S-400	06/13/69	61	08/14/69	8.2	----	----
S-300	06/13/69	62	08/14/69	10.2	----	----
S-200	06/13/69	51	08/14/69	21.5	05/25/70	4
S-100	06/13/69	42	08/14/69	17.5	----	----
A-200	06/11/69	50	08/21/69	18.0	04/21/70	12
A-100	06/11/69	47	08/19/69	9.5	----	----
R-100	06/12/69	64	08/19/69	7.8	----	----
L-100	----	----	08/21/69	14.0	----	----
I-100	06/24/69	22	08/18/69	10.0	04/21/70	34

Some tributaries contribute substantially to the turbidity of the Sagavanirktok mainstem. For example, Atigun River consistently has higher turbidity than the Sagavanirktok River station (S-1300) located immediately upstream from the confluence of the two rivers and causes higher turbidity at the next Sagavanirktok River station downstream. The Ribdon River exerts a similar effect on the turbidity found at the station (S-1000) located down-

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stream from the confluence. The Ivishak River has an opposite and substantial effect on turbidity at station S-700 by contributing a large volume of water with consistently lower turbidity than that of the mainstem Sagavanirktok River at station S-800.

Color

Color is defined as the "true" color of the water from which the turbidity has been removed (Standard Methods, American Public Health Association, 1965). The sources of color are often complex organic compounds with components derived from iron, manganese, humus and peat substances, plankton, aquatic macrophytes and plant material of terrestrial origin. No attempts were made to identify the source of the substances adding color in this study.

Color data from 19 stations along the Sagavanirktok River, including 5 tributaries, are presented in Table 14. Color units ranged from 0 to 105 with the lowest being found during August and April-May while significantly higher numbers were recorded during June, shortly after the peak of breakup when much of the river discharge originates from snow-melt, which travels some distance through and over the tundra, and dissolves various substances before entering the stream.

TABLE 14. COLOR DATA FOR SAG RIVER BASIN

Station	Date	Color Units	Date	Color Units	Date	Color Units
S-1300	06/11/69	35	08/19/69	2	----	----
S-1200	06/12/69	37	08/19/69	2	----	----
S-1100	06/12/69	70	08/19/69	3	----	----
S-1000	06/12/69	70	08/20/69	1	----	----
S-900	06/12/69	70	08/21/69	3	04/22/70	2
S-800	06/12/69	47	08/14/69	4	04/22/70	7
S-700	06/24/69	50	08/14/69	3	----	----
S-600	06/24/69	27	08/14/69	4	----	----
S-500	06/13/69	55	08/14/69	3	----	----
S-400	06/13/69	44	08/14/69	3	----	----
S-300	06/13/69	49	08/14/69	5	----	----
S-200	06/13/69	50	08/14/69	3	05/25/70	0
S-100	06/13/69	105	08/14/69	4	----	----
A-200	06/11/69	46	08/21/69	1	04/21/70	4
A-100	06/11/69	44	08/19/69	2	----	----
R-100	06/12/69	45	08/18/69	1	----	----
L-100	----	----	08/21/69	4	----	----
I-100	06/24/69	37	08/17/69	8	04/21/70	4

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Fixed Suspended Solids

Fixed suspended solids is defined as filterable inorganic material that has been suspended in the water column. The turbulence and mixing action of current, responsible for this suspension, changes with time and meteorological conditions. Highest concentrations were found during the spring post breakup conditions in June and considerably lower concentrations were found during the lower water stage in August (Table 15). Fixed suspended solids in the Sagavanirktok River ranged from 0 to 325 mg/l and for any sample period were consistently highest at stations located near the mouth.

TABLE 15. FIXED SUSPENDED SOLIDS IN SAG RIVER BASIN

Station	Date	Fixed Suspended Solids mg/l	Date	Fixed Suspended Solids mg/l
S-1300	06/11/69	63	08/14/69	0
S-1200	06/12/69	93	08/19/69	8
S-1100	06/12/69	85	08/19/69	2
S-1000	06/12/69	113	08/20/69	8
S-900	06/12/69	103	08/21/69	8
S-800	06/12/69	183	08/14/69	30
S-700	06/24/69	45	08/14/69	10
S-600	06/24/69	54	08/14/69	10
S-500	06/13/69	119	08/14/69	23
S-400	06/13/69	325	08/14/69	12
S-300	06/13/69	295	08/14/69	12
S-200	06/13/69	115	08/14/69	44
S-100	06/13/69	108	08/14/69	14
A-200	06/11/69	219	08/21/69	4
A-100	06/11/69	76	08/19/69	16
R-100	06/11/69	131	08/19/69	8
L-100	----	----	08/21/69	8
I-100	06/24/69	18	08/17/69	5

Nitrogen Forms

Nitrogen is usually found as ammonia, nitrite and nitrate in aquatic systems. All three are not equally abundant and are dependent upon a particular set of conditions and organisms before transformation from one form to another is possible (Hutchinson, 1957). Ammonia and nitrate data are presented in Table 16 and 17, respectively. Trace amounts (less than 0.01 mg/l) of nitrite were consistently found in all samples and therefore are not presented.

TABLE 16. AMMONIA DATA FOR SAG RIVER BASIN

Station	Date	Ammonia mg/l	Date	Ammonia mg/l	Date	Ammonia mg/l
S-1300	06/11/69	0.04	08/19/69	0.05	----	----
S-1200	06/12/69	0.04	08/19/69	0.03	----	----
S-1100	06/12/69	0.04	08/19/69	0.03	----	----
S-1000	06/12/69	0.02	08/20/69	0.02	----	----
S-900	06/12/69	0.02	08/21/69	0.03	04/22/70	0.01
S-800	06/12/69	0.04	08/14/69	0.03	04/22/70	0.18
S-700	06/24/69	0.02	08/14/69	0.04	----	----
S-600	06/24/69	0.02	08/14/69	0.03	----	----
S-500	06/13/69	0.04	08/14/69	0.04	----	----
S-400	06/13/69	0.04	08/14/69	0.04	----	----
S-300	06/13/69	0.04	08/14/69	0.07	----	----
S-200	06/13/69	0.09	08/14/69	0.04	05/25/70	0.4
S-100	06/13/69	0.02	08/14/69	0.03	----	----
A-200	06/11/69	0.04	08/21/69	0.02	04/21/70	0.01
A-100	06/11/69	0.04	08/19/69	0.04	----	----
R-100	06/12/69	0.02	08/19/69	0.02	----	----
I-100	06/24/69	0.02	08/17/69	0.03	04/21/70	0.01

TABLE 17. NITRATE DATA FOR SAG RIVER BASIN

Station	Date	Nitrate mg/l	Date	Nitrate mg/l	Date	Nitrate mg/l
S-1300	06/11/69	0.10	08/19/69	0.15	----	----
S-1200	06/12/69	0.10	08/19/69	0.10	----	----
S-1100	06/12/69	0.09	08/19/69	0.10	----	----
S-1000	06/12/69	0.08	08/20/69	0.07	----	----
S-900	06/12/69	0.07	08/21/69	0.09	04/22/70	0.09
S-800	06/12/69	0.08	08/14/69	0.10	04/22/70	0.76
S-700	06/24/69	0.11	08/14/69	0.09	----	----
S-600	06/24/69	0.11	08.14/69	0.09	----	----
S-500	06/13/69	0.09	08/14/69	0.09	----	----
S-400	06/13/69	0.08	08/14/69	0.10	----	----
S-300	06/13/69	0.08	08/14/69	0.12	----	----
S-200	06/13/69	0.07	08/14/69	0.10	05/25/70	0.48
S-100	06/13/69	0.05	08/14/69	0.09	----	----
A-200	06/11/69	0.11	08/21/69	0.10	04/21/70	0.06
A-100	06/11/69	0.09	08/19/69	0.09	----	----
R-100	06/12/69	0.07	08/19/69	0.07	----	----
L-100	----	----	08/21/69	0.09	----	----
I-100	06/24/69	0.10	08/17/69	0.06	04/21/70	0.13

Concentrations of nitrate ranged from 0.05 to 0.76 mg/l. The highest values (0.48 and 0.76 mg/l) were recorded during the April sample period although other samples collected during April were within the 0.06 to 0.13 mg/l range. Of those samples collected during June and August, the lowest concentrations came from Galbraith Outlet (0.02 and 0.03 mg/l); most samples ranged from 0.08 to 0.10 mg/l with no obvious pattern. Occasionally higher concentrations were found along the entire drainage.

Concentrations of ammonia ranged from 0.01 to 0.18 mg/l with both extremes found during the April sampling trip. Samples collected during both the June and August trips revealed intermediate concentrations with the low (0.01 mg/l) for each trip generally found in the Foothill Province and the highs (0.07 and 0.09 mg/l) found near the mouth. Reaches of the Sagavanirktok River below the confluence of the Ribdon and Ivishak Rivers generally contained lower concentrations of ammonia than reaches above the respective confluence.

Phosphorus

In nature phosphorus is generally found as orthophosphate and particulate phosphate. The samples were analyzed as orthophosphate and total phosphate. The ability of the phosphate ion to form complexes with many of the dissolved compounds that are found in natural water and the affinity for phosphate by aquatic organisms causes the concentrations of phosphate compounds in solution to be relatively and consistently found in amounts less than 0.01 mg/l and for this reason have not been presented. Total phosphate (orthophosphate plus particulate phosphate) ranged from 0.01 to 0.52 (Table 18). Concentrations of total phosphate were slightly above 0.01 mg/l in the headwaters but increased to 0.035 and 0.05 mg/l (June and August, respectively) near the mouth. Samples collected during August and April from stations along the river were low in concentrations of total phosphate (0.01 - 0.02 mg/l) although samples from Galbraith Lake and near the mouth of the Sagavanirktok were often higher.

Silica

Concentrations of silica ranged from 0.7 to 12.5 mg/l (Table 19). The highest concentrations were recorded from samples collected during April 1970 (3.6 mg/l to 12.5 mg/l). Samples collected during the June and August intervals along the entire river generally fluctuated slightly near 1.6 mg/l, although wide departures were found. Tributaries, Atigun, Ribdon and Ivishak may have had small localized effects in areas downstream from their respective confluences with the Sagavanirktok River. Ivishak is above, Ribdon is near, and Atigun is below, all compared to mainstem concentration.

Sodium and Potassium

Concentrations of sodium ranged from 0.32 to 90.0 mg/l (Table 20). An extremely high concentration of 90.0 mg/l was analyzed from a sample collected during April at station S-800 near Sagwon although other samples collected during April were also high. Sodium concentrations from samples collected during June ranged from 0.32 to 1.12 mg/l while those collected during August

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TABLE 18. PHOSPHATE DATA FOR SAG RIVER BASIN

Station	Date	Total Phosphate mg/l	Date	Total Phosphate mg/l	Date	Total Phosphate mg/l
S-1300	06/11/69	0.01	08/19/69	0.01	----	----
S-1200	06/12/69	0.01	08/19/69	0.02	----	----
S-1100	06/12/69	0.01	08/19/69	0.01	----	----
S-1000	06/12/69	0.02	08/20/69	0.00	----	----
S-900	06/12/69	0.02	08/21/69	0.01	04/22/70	0.01
S-800	06/12/69	0.02	08/14/69	0.02	04/22/70	0.01
S-700	06/24/69	0.01	08/14/69	0.01	----	----
S-600	06/24/69	0.01	06/14/69	0.02	----	----
S-500	06/13/69	0.03	08/14/69	0.02	----	----
S-400	06/13/69	0.02	08/14/69	0.02	----	----
S-300	06/13/69	0.03	08/14/69	0.07	----	----
S-200	06/13/69	0.04	08/14/69	0.03	05/25/70	----
S-100	06/13/69	0.04	08/14/69	0.03	----	----
A-200	06/11/69	0.01	08/21/69	0.01	04/21/70	0.01
A-100	06/11/69	0.01	08/19/69	0.02	----	----
R-100	06/12/69	0.01	08/19/69	0.00	----	----
L-100	----	----	08/21/69	0.00	----	----
I-100	06/24/69	0.02	08/17/69	0.01	----	----

TABLE 19. SILICA DATA FOR SAG RIVER BASIN

Station	Date	Silica mg/l	Date	Silica mg/l	Date	Silica mg/l
S-1300	06/11/69	0.7	08/19/69	1.6	----	----
S-1200	06/12/69	1.0	08/19/69	1.4	----	----
S-1100	06/12/69	1.2	08/19/69	1.5	----	----
S-1000	06/12/69	1.6	08/20/69	2.0	----	----
S-900	06/12/69	1.3	08/21/69	2.1	04/22/70	5.3
S-800	06/12/69	1.6	08/14/69	1.4	04/22/70	12.5
S-700	06/24/69	2.7	08/14/69	1.4	----	----
S-600	06/24/69	2.0	06/14/69	1.6	----	----
S-500	06/13/69	1.9	08/14/69	1.6	----	----
S-400	06/13/69	1.5	08/14/69	1.9	----	----
S-300	06/13/69	1.5	08/14/69	1.2	----	----
S-200	06/13/69	1.6	08/14/69	2.5	05/25/70	3.6
S-100	06/13/69	1.4	08/14/69	1.6	----	----
A-200	06/11/69	0.9	08/21/69	1.4	04/21/70	1.1
A-100	06/11/69	0.7	08/19/69	1.2	----	----
R-100	06/12/69	1.8	08/19/69	2.0	----	----
I-100	06/24/69	3.0	08/17/69	1.8	04/21/70	7.2

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TABLE 20. SODIUM DATA FOR SAG RIVER BASIN

Station	Date	Sodium mg/l	Date	Sodium mg/l	Date	Sodium mg/l
S-1300	06/11/69	0.66	08/19/69	0.41	----	----
S-1200	06/12/69	0.67	08/19/69	1.41	----	----
S-1100	06/12/69	0.53	08/19/69	1.15	----	----
S-1000	06/12/69	0.41	08/20/69	0.51	----	----
S-900	06/12/69	0.46	08/21/69	0.77	04/22/70	2.82
S-800	06/12/69	0.45	08/14/69	0.62	04/22/70	90.0
S-700	06/24/69	0.40	08/14/69	0.64	----	----
S-600	06/24/69	0.40	08/14/69	0.66	----	----
S-500	06/13/69	0.45	08/14/69	0.56	----	----
S-400	06/13/69	0.45	08/14/69	0.37	----	----
S-300	06/13/69	0.51	08/14/69	0.64	----	----
S-200	06/13/69	0.53	08/14/69	0.57	05/25/70	----
S-100	06/13/69	1.12	08/14/69	0.41	----	----
A-200	06/11/69	0.53	08/21/69	0.83	04/21/70	0.83
A-100	06/11/69	0.53	08/19/69	0.83	----	----
R-100	06/12/69	0.32	08/19/69	0.32	----	----
L-100	----	----	08/21/69	0.67	----	----
I-100	06/24/69	0.48	08/17/69	0.53	04/21/70	1.18

ranged from 0.28 to 1.41 mg/l. The lowest concentrations for each interval were found in Ribdon River and Galbraith outlet. August values at any station were usually lower than those found in June at the same station.

Concentrations of potassium ranged from 0.13 to 1.97 mg/l (Table 21). As in sodium, the higher concentration of potassium was found during April at staion S-800. In general, highest concentrations were found during April and the lowest during August.

Calcium and Magnesium

Concentrations of calcium ranged from 11.7 to 295.0 mg/l (Table 22). At most stations, the highest concentrations were found during April. Samples collected during August were higher than those collected during June. Also, concentrations generally increased from the headwaters to the mouth.

Concentrations of magnesium ranged from a low 2.9 mg/l in June 1969, to a high of 48.0 mg/l in April 1970 (Table 23). Data collected during June revealed a range of concentration from 4.3 to 5.5 mg/l with no apparent trend from the headwaters toward the mouth. Concentrations from samples collected during August were consistently higher than those collected from the same stations in June, but concentrations gradually increased from the headwaters to the mouth. Samples collected in April were consistently and substantially more concentrated than those collected in either June or August.

TABLE 21. POTASSIUM DATA FOR SAG RIVER BASIN

Station	Date	Potassium mg/l	Date	Potassium mg/l	Date	Potassium mg/l
S-1300	06/11/69	0.34	08/19/69	0.35	----	----
S-1200	06/12/69	0.43	08/19/69	0.43	----	----
S-1100	06/12/69	0.45	08/19/69	0.35	----	----
S-1000	06/12/69	0.31	08/20/69	0.20	----	----
S-900	06/12/69	0.36	08/21/69	0.27	04/22/70	0.70
S-800	06/12/69	0.49	08/14/69	0.29	04/22/70	1.97
S-700	06/24/69	0.18	08/14/69	0.20	----	----
S-600	06/24/69	0.24	08/14/69	0.19	----	----
S-500	06/13/69	0.35	08/14/69	0.20	----	----
S-400	06/13/69	0.44	08/14/69	0.20	----	----
S-300	06/13/69	0.50	08/14/69	0.20	----	----
S-200	06/13/69	0.55	08/14/69	0.28	05/25/70	----
S-100	06/13/69	0.73	08/14/69	0.24	----	----
A-200	06/11/69	0.45	08/21/69	0.43	04/21/70	0.51
A-100	06/11/69	0.49	08/19/69	0.41	----	----
L-100	----	----	08/21/69	0.13	----	----
R-100	06/12/69	0.29	08/19/69	0.16	----	----
I-100	06/24/69	0.17	08/17/69	0.14	04/21/70	0.32

TABLE 22. CALCIUM DATA FOR SAG RIVER BASIN

Station	Date	Calcium mg/l	Date	Calcium mg/l	Date	Calcium mg/l
S-1300	06/11/69	11.6	08/19/69	16.1	----	----
S-1200	06/12/69	14.8	08/19/69	20.2	----	----
S-1100	06/12/69	19.2	08/19/69	24.1	----	----
S-1000	06/12/69	30.0	08/20/69	38.1	----	----
S-900	06/12/69	25.6	08/21/69	35.1	04/22/70	89.0
S-800	06/12/69	27.8	08/14/69	32.7	04/22/70	295.0
S-700	06/24/69	14.7	08/14/69	39.0	----	----
S-600	06/24/69	15.7	08/14/69	36.4	----	----
S-500	06/13/69	30.0	08/14/69	38.8	----	----
S-400	06/13/69	30.0	08/14/69	36.1	----	----
S-300	06/13/69	29.6	08/14/69	38.1	----	----
S-200	06/13/69	28.6	08.14/69	41.5	05/25/70	----
S-100	06/13/69	32.4	08/14/69	38.5	----	----
A-200	06/11/69	11.4	08/21/69	22.8	04/21/70	16.7
A-100	06/11/69	17.3	08/19/69	23.6	----	----
L-100	----	----	08/21/69	45.8	----	----
R-100	06/12/69	35.4	08/19/69	31.0	----	----
I-100	06/24/69	20.2	08/17/69	38.5	04/21/70	93.0

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TABLE 23. MAGNESIUM DATA FOR SAG RIVER BASIN

Station	Date	Magnesium mg/l	Date	Magnesium mg/l	Date	Magnesium mg/l
S-1300	06/11/69	3.0	08/19/69	4.7	----	----
S-1200	06/12/69	3.2	08/19/69	5.0	----	----
S-1100	06/12/69	2.9	08/19/69	4.5	----	----
S-1000	06/12/69	3.7	08/20/69	5.5	----	----
S-900	06/12/69	3.3	08/21/69	4.2	04/22/70	17.5
S-800	06/12/69	3.6	08/14/69	4.3	04/22/70	48.0
S-700	06/24/69	3.8	08/14/69	5.3	----	----
S-600	06/24/69	3.3	08/14/69	5.0	----	----
S-500	06/13/69	4.0	08/14/69	5.4	----	----
S-400	06/13/69	4.0	08/14/69	5.0	----	----
S-300	06/13/69	4.0	08/14/69	4.6	----	----
S-200	06/13/69	3.5	08/14/69	5.0	05/25/70	----
S-100	06/13/69	3.6	08/14/69	5.5	----	----
A-200	06/11/69	3.4	08/21/69	5.9	04/21/70	4.1
A-100	06/11/69	3.5	08/19/69	5.7	----	----
R-100	06/12/69	4.3	08/19/69	5.1	----	----
L-100	----	----	08/21/69	2.4	----	----
I-100	06/24/69	5.7	08/17/69	5.2	04/21/70	16.2

Iron

In nature, iron is generally not found in high enough concentrations to appreciably affect water quality (Love, 1965). However, water flowing through iron bearing substrate (Sawyer and McCarty, 1967) may contain significant concentrations as high as 50 mg/l (Hem, 1970). In the Sagavanirktok River, a 0.1 to 1.1 mg/l range was found (Table 24), although $\leq$0.3 mg/l was most common. No samples were collected in June so no comparison can be made between June and August samples. It is probable that June samples would have contained less iron that the August samples. Surprisingly, an August sample contained the most iron (1.1 mg/l), although similar concentrations were found in April.

Chloride

Concentrations of chloride were generally within the 0.30 to 1.66 mg/l range (Table 25). The highest concentration (2.33 mg/l) was found at S-100 during June and probably be correlated to intrusion of salt water from the Beaufort Sea. (High concentrations of sodium were also detected at the same station and during the same interval.) During June, samples collected at most stations contained 0.30 mg/l chloride. During August concentrations were generally higher.

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TABLE 24. IRON DATA FOR SAG RIVER BASIN

Station	Date	Iron mg/l	Date	Iron mg/l	Date	Iron mg/l
S-1300	06/11/69	----	08/19/69	0.2	----	----
S-1200	06/12/69	----	08/19/69	0.3	----	----
S-1100	06/12/69	----	08/19/69	0.2	----	----
S-1000	06/12/69	----	08/20/69	0.1	----	----
S-900	06/12/69	----	08/21/69	0.1	04/22/70	0.94
S-800	06/12/69	----	08/14/69	1.1	04/22/70	0.5
S-700	06/24/69	----	08/14/69	0.2	----	----
S-600	06/24/69	----	08/14/69	0.2	----	----
S-500	06/13/69	----	08/14/69	0.3	----	----
S-400	06/13/69	----	08/14/69	0.3	----	----
S-300	06/13/69	----	08/14/69	0.3	----	----
S-200	06/13/69	----	08/14/69	0.7	05/25/70	----
S-100	06/13/69	----	08/14/69	0.4	----	----
A-200	06/11/69	----	08/21/69	0.3	04/21/70	0.52
A-100	06/11/69	----	08/19/69	0.6	----	----
R-100	06/12/69	----	08/19/69	0.1	----	----
L-100	----	----	08/21/69	0.1	----	----
I-100	06/24/69	----	08/17/69	0.1	04/21/70	0.5

TABLE 25. CHLORIDE DATA FOR SAG RIVER BASIN

Station	Date	Chloride mg/l	Date	Chloride mg/l	Date	Chloride mg/l
S-1300	06/11/69	0.91	08/19/69	0.91	----	----
S-1200	06/12/69	0.50	08/19/69	0.91	----	----
S-1100	06/12/69	0.30	08/19/69	0.91	----	----
S-1000	06/12/69	0.30	08/20/69	1.11	----	----
S-900	06/12/69	0.30	08/21/69	1.11	04/22/70	0.48
S-800	06/12/69	0.30	08/14/69	1.11	04/22/70	1.66
S-700	06/24/69	0.30	08/14/69	1.51	----	----
S-600	06/24/69	0.30	08/14/69	1.31	----	----
S-500	06/13/69	0.30	08/14/69	0.50	----	----
S-400	06/13/69	0.30	08/14/69	1.01	----	----
S-300	06/13/69	0.30	08/14/69	1.31	----	----
S-200	06/13/69	0.30	08/14/69	0.3	05/25/70	----
S-100	06/13/69	2.33	08/14/69	0.5	----	----
S-200	06/11/69	0.30	08/21/69	0.91	04/21/70	0.48
A-100	06/11/69	0.50	08/19/69	0.91	----	----
R-100	06/12/69	0.50	08/19/69	0.91	----	----
L-100	----	----	08/21/69	1.11	----	----
I-100	06/24/69	0.50	08/17/69	1.11	04/21/70	0.39

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Specific Conductance

Specific conductance is a measure of the ability of water to conduct electric current. This parameter is affected by all ionized substances found in water, although some compounds such as sodium carbonate and sodium chloride are better conductors than others.

The concentrations ranged from 85 umhos at S-1300 in June, to 1700 umhos at station S-800 in April (Table 26). In general, the lowest conductivity was found in June, the highest in April, and the intermediate in August. Also, the lowest conductivity for any sampling interval was generally found at the stations located at highest elevation on the river, i.e., S-1300.

TABLE 26. SPECIFIC CONDUCTANCE DATA FOR SAG RIVER BASIN

Station	Date	Specific Conductance μmhos/m	Date	Specific Conductance μmhos/cm	Date	Specific Conductance μmhos/cm
S-1300	06/11/69	85	08/19/69	128	----	----
S-1200	06/12/69	99	08/19/69	150	----	----
S-1100	06/12/69	112	08/19/69	190	----	----
S-1000	06/12/69	128	08/20/69	242	----	----
S-900	06/12/69	132	08/21/69	215	04/22/70	660
S-800	06/12/69	130	08/14/69	195	04/22/70	1700
S-700	06/24/69	179	08/14/69	170	----	----
S-600	06/24/69	162	08/14/69	220	----	----
S-500	06/13/69	148	08/14/69	179	----	----
S-400	06/13/69	140	08/14/69	215	----	----
S-300	06/13/69	133	08/14/69	185	----	----
S-200	06/13/69	145	08/14/69	218	05/25/70	782
S-100	06/13/69	113	08/14/69	143	----	782
A-200	06/11/69	86	08/21/69	158	04/21/70	125
A-100	06/11/69	115	08/19/69	161	----	----
R-100	06/12/69	170	08/19/69	215	----	----
L-100	----	----	08/21/69	270	----	----
T-100	06/24/69	210	08/17/69	222	04/21/70	480

Alkalinity

In this discussion, alkalinity is defined as the capacity of water to neutralize acids. The primary forms of alkalinity are hydroxide, carbonate and bicarbonate, each of which is found over a different pH range. Since the pH of the Sagavanirktok River varied from 7.6 to 8.2 during the summer, the primary source of alkalinity at this range is probably bicarbonate because the pH range of this anion is 4.3-8.3. Although the above ions are probably the most important, other ions that may contribute to alkalinity include phosphates, silicates and organic ions.

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Alkalinity ranged from 24 to 112 during the June and August intervals and from 273 to 875 during April (Table 27). For the June and August intervals, alkalinity was generally lowest in the headwaters although wide departures from the trend can be found. Also, alkalinity at each station during August was generally higher than at the respective stations during June. Samples collected during April contained concentrations of alkalinity that were consistently and drastically higher than those found at any other time of the year.

TABLE 27. ALKALINITY DATA FOR SAG RIVER BASIN

Station	Date	Total Alkalinity mg/l	Date	Total Alkalinity mg/l	Date	Total Alkalinity mg/l
S-1300	06/11/69	36.2	08/19/69	50.5	----	----
S-1200	06/12/69	44.1	08/19/69	63.4	----	----
S-1100	06/12/69	52.5	08/19/69	78.4	----	----
S-1000	06/12/69	70.4	08/20/69	24	----	----
S-900	06/12/69	64.5	08/21/69	104	04/22/70	314
S-800	06/12/69	66.7	08/14/69	96.0	04/22/70	875
S-700	06/24/69	88.1	08/14/69	107	----	----
S-600	06/24/69	75.1	08/14/69	106	----	----
S-500	06/13/69	76.1	08/14/69	107	----	----
S-400	06/13/69	69.6	08/14/69	104	----	----
S-300	06/13/69	68.2	08/14/69	101	----	----
S-200	06/13/69	70.5	08/14/69	106	05/25/70	273
S-100	06/13/69	50.9	08/14/69	112	----	----
A-200	06/11/69	36.4	08/21/69	71.8	04/21/70	54.0
A-100	06/11/69	52.4	08/19/69	72.5	----	----
R-100	06/12/69	84.1	08/19/69	123	----	----
I-100	06/24/69	93.8	08/17/69	107	04/21/70	204

Total Hardness

Total hardness is a measure of the total calcium, magnesium, iron, maganese, aluminum, strontium and zinc ions present in water; although when present in appreciable concentrations, other cations may strongly affect total hardness.

In the Sagavanirktok River mainstem, total hardness ranged from 40.0 mg/l at S-1300 during June to 952.0 mg/l at S-800 during April (Table 28). At individual stations, concentrations were consistently lower during June than in August which in turn were lower than those found during April. Concentrations for any sampling interval were usually lowest at the stations in the mountains (i.e., S-1200, S-1300) and generally increased when proceeding downstream until the confluence with Ribdon River (S-1000). This pattern closely parallels the trend shown by concentrations of total calcium.

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TABLE 28. TOTAL HARDNESS DATA FOR SAG RIVER BASIN

Station	Date	Total Hardness mg/l	Date	Total Hardness mg/l	Date	Total Hardness mg/l
S-1300	06/11/69	40.0	08/19/69	53.5	----	----
S-1200	06/12/69	52.0	08/19/69	66.7	----	----
S-1100	06/12/69	61.0	08/19/69	74.7	----	----
S-1000	06/12/69	85.0	08/20/69	118	----	----
S-900	06/12/69	78.0	08/21/69	113	04/22/70	349
S-800	06/12/69	79.0	08/14/69	106	04/22/70	952
S-700	06/24/69	80.0	08/14/69	117	----	----
S-600	06/24/69	77.0	08/14/69	117	----	----
S-500	06/13/69	87.0	08/14/69	119	----	----
S-400	06/13/69	86.0	08/14/69	114	----	----
S-300	06/13/69	84.0	08/14/69	112	----	----
S-200	06/13/69	86.0	08/14/69	107	05/25/69	----
S-100	06/13/69	85.0	08/14/69	109	----	----
A-200	06/11/69	42.0	08/21/69	82.8	04/21/70	54.9
A-100	06/11/69	44.0	08/19/69	74.7	----	----
R-100	06/12/69	93.0	08/19/69	105	----	----
L-100	----	----	08/21/69	128	----	----
I-100	06/24/69	100.0	08/17/69	114	04/21/70	232

pH

All of the water samples from the Sagavanirktok River basin were slightly alkaline with a pH range from 7.25 to 8.55 (Table 29). This range is well within the 6.5 to 8.5 normal range for freshwater described by Hem (1970).

Samples collected in June ranged from 7.6 to near 8.2. In August, some tendency was shown toward increasing pH when proceeding downstream from the mountain area to above Sagwon, but from this area to Prudhoe Bay, pH generally remained within the 8.0-8.2 range. In general, the most alkaline conditions were found during the August sample interval and the least alkaline conditions, approaching neutral, were observed during April.

Total Organic Carbon

Concentrations of total organic carbon ranged from 3 to 22 mg/l (Table 30). Both of these extremes were recorded during the winter sampling period with the highest concentrations at station S-200 in late May and the lowest at station S-900 about one month earlier. Most of the samples collected during the June and August sampling periods were within the 5 to 10 mg/l range. The highest concentrations for each sample period were found at stations located near the mouth.

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TABLE 29. pH DATA FOR SAG RIVER BASIN

Station	Date	pH	Date	pH	Date	pH
S-1300	06/11/69	7.80	08/19/69	7.75	----	----
S-1200	06/12/69	7.80	06/19/69	7.96	----	----
S-1100	06/12/69	7.90	08/19/69	8.06	----	----
S-1000	06/12/69	7.75	08/20.69	8.15	----	----
S-900	06/12/69	8.01	08/21/69	8.09	04/22/70	7.72
S-800	06/12/69	7.80	08/14/69	8.06	04/22/70	7.73
S-700	06/24/69	8.02	08/14/69	8.06	----	----
S-600	06/24/69	7.95	08/14/69	8.12	----	----
S-500	06/13/69	7.92	08/14/69	8.02	----	----
S-400	06/13/69	7.60	08/14/69	8.12	----	----
S-300	06/13/69	7.80	08/14/69	8.08	----	----
S-200	06/13/69	7.73	08/14/69	8.11	05/25/70	7.25
S-100	06/13/69	7.78	08/14/69	7.71	----	----
A-200	06/11/69	7.68	08/21/69	7.91	04/21/70	8.10
A-100	06/11/69	8.22	08/19/69	7.95	----	----
R-100	06/12/69	7.95	08/19/69	8.17	----	----
L-100	----	----	08/21/69	8.14	----	----
I-100	06/24/69	7.97	08/17/69	7.81	04/21/70	8.55

TABLE 30. TOTAL ORGANIC CARBON FOR SAG RIVER BASIN

Station	Date	TOC mg/l	Date	TOC mg/l	Date	TOC mg/l
S-1300	06/11/69	6	08/19/69	7	----	----
S-1200	06/12/69	10	06/19/69	5	----	----
S-1100	06/12/69	8	08/19/69	7	----	----
S-1000	06/12/69	8	08/20/69	9	----	----
S-900	06/12/69	8	08/21/69	7	04/22/70	3
S-800	06/12/69	8	08/14/69	10	04/22/70	6
S-700	06/24/69	7	08/14/69	8	----	----
S-600	06/24/69	7	08/14/69	4	----	----
S-500	06/13/69	9	08/14/69	6	----	----
S-400	06/13/69	9	08/14/69	7	----	----
S-300	06/13/69	12	08/14/69	8	----	----
S-200	06/13/69	11	08/14/69	10	05/25/70	22
S-100	06/13/69	14	08/14/69	10	----	----
A-200	06/11/69	9	08/21/69	6	04/21/70	3
A-100	06/11/69	9	08/19/69	8	----	----
R-100	06/12/69	9	08/19/69	5	----	----
L-100	----	----	08/21/69	8	----	----
I-100	06/24/69	8	08/17/69	10	04/21/70	6

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CANNING AND SHAVIOVIK RIVERS

Physical and chemical data of the Canning River are presented for two reasons. First, the Canning River was chosen as the control stream of the study. Therefore, data from this river are presented and often compared to those of the Sagavanirktok River. Secondly, the data collected from the Canning River will expand the information available on rivers of the Arctic. In addition, data from the Shaviovik River are presented as representative of a smaller stream system that traverses part of the foothill and all of the coastal province, further expanding the available information.

Most water quality parameters of the Canning and the Shaviovik Rivers fall within the ranges established by the respective parameters of the Sagavanirktok River. Also the general patterns observed in the Canning and Shaviovik Rivers were usually similar to those documented in the Sagavanirktok River, although some differences exist.

Water temperature data from the Canning River reveal seasonal ranges similar to the Sagavanirktok River ranges for comparable intervals and a decreasing water temperature pattern when proceeding downstream (Table 31). The temperatures ranged from 2.7°C (40.5°F) to 9.2°C (48.6°F) during the June interval and 3.7°C (38.7°F) to 6.2°C (43.2°F) during the August samples with the highest temperatures recorded at the upper stations (SH-300 and CA-400) during both intervals. These data are similar to Sagavanirktok River data collected during similar periods from stations at comparable latitudes.

TABLE 31. WATER AND AIR TEMPERATURES IN CANNING AND SHAVIOVIK RIVER BASINS

Station	Date	Air °C(°F)	Water °C(°F)	Date	Air °C(°F)	Water °C(°F)
CA-400	----	----	----	08/15/69	8.3 (46.9)	6.2 (43.2)
CA-300	06/24/69	13.9 (57)	9.2 (40.6)	08/15/69	5.6 (42.0)	5.8 (46.6)
CA-200	06/24/69	6.7 (44)	8.8 (46.8)	08/15/69	2.8 (37.0)	3.7 (38.7)
CA-100	06/24/69	2.2 (36)	4.7 (40.5)	08/20/69	----	----
SH-400	06/25/69	12.2 (54)	11.0 (51.8)	08/20/69	2.2 (35.6)	1.8 (35.2)
SH-300	06/25/69	14.4 (58)	10.9 (51.6)	08/20/69	2.2 (35.6)	2.8 (37.0)
SH-200	06/25/69	(59)	11.8 (53.2)	08/20/69	3.3 (37.9)	2.9 (37.2)
SH-100	06/25/69	14.4 (58)	12.8 (55.)	08/20/69	4.4 (39.9)	3.4 (38.1)

Data from four stations on the Shaviovik River reveal significantly higher water temperatures and a small but reverse trend along the length of the river (Table 31). The Shaviovik tends to warm up when proceeding downstream. These stations are located at latitudes similar to the S-600 and S-700 on the Sagavanirktok River and the data were collected on the same dates when the highest temperatures were recorded from other streams. As expected, the air temperatures in both stream systems ranged widely depending upon the climatic conditions at the time of sampling. Air temperatures ranged from

2.2°C (35.6°F) to 15.0°C (59°F) in June and from 2.2°C (35.6°F) to 8.3°C (46.9°F) in August. Water temperatures ranged from 10.9°C (51.6°F) to 12.8°C (55.0°F) on June 25 and from 1.8°C (35.2°F) to 3.4°C (38.1°F) on August 20. On both dates, the coolest water was found at the highest stations and the warmest water at the mouth.

Discharge measurements from both rivers are presented in Table 32. Comparison of the discharge data shows that the Canning discharge is smaller than the Sagavanirktok River discharge and approximately an order of magnitude larger than the Shaviovik discharge. It could be expected that the smaller system would be more rapidly responsive to changes in air temperature than larger stream systems.

TABLE 32. STREAMFLOW IN CANNING AND SHAVIOVIK RIVERS

Station	Date	Cu. Ft./Sec.
CA-200	08/15/69	1500
SH-400	08/20/69	1060
SH-100	08/20/69	137
SH-400	08/20/69	71

Turbidity in the Canning and Shaviovik Rivers ranged from 2.8 to 43 JTU and 2.8 to 11.5 JTU respectively (Table 33) and were generally near the lower limit of the range of the Sagavanirktok River.

TABLE 33. TURBIDITY IN CANNING AND SHAVIOVIK RIVERS

Station	Date	Turbidity JTU	Date	Turbidity JTU
CA-400	----	----	08/15/69	10.0
CA-300	06/24/69	43	08/15/69	9.8
CA-200	06/24/69	41	08/15/69	2.8
CA-100	06/24/69	7.8	08/20/69	----
SH-400	06/25/69	9.6	08/20/69	11.5
SH-300	06/25/69	10	08/20/69	10.0
SH-200	06/25/69	9.4	08/20/69	7.1
SH-100	06/25/69	10	08/20/69	2.8

Samples collected from CA-200 (41 JTU) and CA-300 (43 JTU) in June were outside of the established range, but not outstandingly high. Color units in both rivers were consistently higher in June than in August; in some cases,

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the interval differences were a magnitude apart (Table 34). This pattern is similar to that established in the Sagavanirktok River. It is probable that the differences are related to effects of spring breakup. In the Canning River, fixed suspended solids concentrations were similar to concentrations found in the upper reaches of the Sagavanirktok River (Table 35). Statements can be made about the August data collected from the Shaviovik River but during June, fixed suspended solids concentrations were significantly lower.

TABLE 34. COLOR IN THE CANNING AND SHAVIOVIK RIVERS

Station	Date	Color Units	Date	Color Units
CA-400	----	----	08/15/69	2
CA-300	06/24/69	28	08/15/69	1
CA-200	06/24/69	10	08/15/69	2
CA-100	06/24/69	31	08/20/69	----
SH-400	06/25/69	32	08/20/69	3
SH-300	06/25/69	55	08/20/69	4
SH-200	06/25/69	37	08/20/69	5
SH-100	06/25/69	39	08/20/69	7

TABLE 35. FIXED SUSPENDED SOLIDS IN THE CANNING AND SHAVIOVIK RIVERS

Station	Date	Fixed Suspended Solids mg/l	Date	Fixed Suspended Solids mg/l
CA-400	----	----	08/15/69	7
CA-300	06/24/69	70	08/15/69	13
CA-200	06/24/69	62	08/15/69	4
CA-100	06/24/69	16	08/20/69	----
SH-400	06/25/69	14	08/20/69	18
SH-300	06/25/69	14	08/20/69	10
SH-200	06/25/69	17	08/20/69	10
SH-100	06/25/69	17	08/20/69	4

Concentrations of most nutrients were quite low in both rivers. Nitrogen was found in relatively low concentrations in both rivers. As in the Sagavanirktok River, the dominant form is nitrate with consistently lower concentrations of ammonia (0.02 - 0.04 mg/l) also present (Table 36). Concentrations of nitrate (Table 37) were usually slightly higher during June

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TABLE 36. AMMONIA IN THE CANNING AND SHAVIOVIK RIVERS

Station	Date	Ammonia mg/l	Date	Ammonia mg/l
CA-300	06/24/69	0.01	08/15/69	0.03
CA-200	06/24/69	0.01	08/15/69	0.04
CA-100	06/24/69	0.02	----	----
SH-400	06/25/69	0.02	08/20/69	0.02
SH-300	06/25/69	0.02	08/20/69	0.04
SH-200	06/25/69	0.02	08/20/69	0.04
SH-100	06/25/69	0.02	08/20/69	0.02

TABLE 37. NITRATE IN THE CANNING AND SHAVIOVIK RIVERS

Station	Date	Nitrate mg/l	Date	Nitrate mg/l
CA-400	----	----	08/15/69	0.06
CA-300	06/24/69	0.01	08/15/69	0.07
CA-200	06/24/69	0.01	08/15/69	0.06
CA-100	06/24/69	0.17	08/20/69	----
SH-400	06/25/69	0.07	08/20/69	0.07
SH-300	06/25/69	0.11	08/20/69	0.08
SH-200	06/25/69	0.09	08/20/69	0.07

(0.09 - 0.17 mg/l) than August (0.06 - 0.08 mg/l). Total phosphate was found in low concentrations or not at all in both rivers (Table 38). Somewhat higher concentrations were found in the Canning River during June.

Silica was reasonably consistent at all stations, ranging from 1.2 to 2.5 mg/l and from 1.8 to 2.0 mg/l in August (Table 39). At each station, slightly higher concentrations were found during June than during August. These concentrations are slightly higher but compare favorably with those of the Sagavanirktok River.

Concentrations of sodium ranged from 0.48 to 1.43 mg/l from samples collected from the Canning River (Table 40). Datum collected from Station CA-100 was significantly higher than all other data and is believed to be caused by salt water intrusion. This range of concentrations is consistent with those generated in the Sagavanirktok River system. Concentrations of sodium were consistently higher in the Shaviovik River (Table 40) than in both

TABLE 38. TOTAL PHOSPHATE IN THE CANNING AND SHAVIOVIK RIVERS

Station	Date	Total Phosphate mg/l	Date	Total Phosphate mg/l
CA-400	----	----	----	----
CA-300	06/24/69	0.10	08/15/69	0.01
CA-200	06/24/69	0.09	08/15/69	0.00
CA-100	06/24/69	0.01	----	----
SH-400	06/25/69	0.00	08/20/69	0.00
SH-300	06/25/69	----	08/20/69	0.01
SH-200	06/25/69	----	08/20/69	0.00
SH-100	06/25/69	----	08/20/69	0.00

TABLE 39. SILICA IN THE CANNING AND SHAVIOVIK RIVERS

Station	Date	Silica mg/l	Date	Silica mg/l
CA-400	----	----	08/15/69	2.0
CA-300	06/24/69	2.2	08/15/69	2.2
CA-200	06/24/69	2.0	08/15/69	1.9
CA-100	06/24/69	1.2	08/15/69	----
SH-400	06/25/69	2.2	08/20/69	1.8
SH-300	06/25/69	2.2	08/20/69	1.9
SH-200	06/25/69	2.5	08/20/69	1.9
SH-100	06/25/69	2.3	08/20/69	1.9

the Canning and Sagavanirktok Rivers. The values ranged from 0.59 to 1.73 mg/l and were approached or exceeded only by rare samples where salt water intrusion was a possibility or by samples collected during winter.

Potassium concentrations in Canning River ranged from 0.13 to 0.33 mg/l (Table 41) and was similar to the low end of the range of data from the Sagavanirktok River. Concentrations of potassium from Shaviovik River ranged from 0.22 to 0.44 mg/l and most samples were higher than those in Canning River.

Calcium concentrations were the highest of all cation concentrations. Calcium ranged from 13.9 to 37.7 mg/l in Canning River and 20.6 to 41.4 mg/l in Shaviovik River (Table 42). These values compare favorably with those from Sagavanirktok River although generally near the high end of the range. Samples collected during August were usually higher in both rivers. This is

TABLE 40. SODIUM IN THE CANNING AND SHAVIOVIK RIVERS

Station	Date	Sodium mg/l	Date	Sodium mg/l
CA-400	----	----	08/15/69	0.54
CA-300	06/24/69	0.48	08/15/69	0.74
CA-200	06/24/69	0.47	08/15/69	0.64
CA-100	06/24/69	1.43	08/20/69	----
SH-400	06/25/69	1.73	08/20/69	1.37
SH-300	06/25/69	1.15	08/20/69	1.18
SH-200	06/25/69	1.15	08/20/69	1.18
SH-100	06/25/69	1.12	08/20/69	1.04

TABLE 41. POTASSIUM IN THE CANNING AND SHAVIOVIK RIVERS

Station	Date	Potassium mg/l	Date	Potassium mg/l
CA-400	----	----	08/15/69	0.24
CA-300	06/24/69	0.13	08/15/69	0.25
CA-200	06/24/69	0.16	08/15/69	0.27
CA-100	06/24/69	0.33	08/20/69	----
SH-400	06/25/69	0.44	08/20/69	0.38
SH-300	06/25/69	0.37	08/20/69	0.41
SH-200	06/25/69	0.22	08/20/69	0.40
SH-100	06/25/69	0.41	08/20/69	0.41

TABLE 42. CALCIUM IN THE CANNING AND SHAVIOVIK RIVERS

Station	Date	Calcium mg/l	Date	Calcium mg/l
CA-400	----	----	08/15/66	34.0
CA-300	06/24/69	22.0	08/15/69	37.7
CA-200	06/24/69	20.5	08/15/69	36.9
CA-100	06/24/69	13.9	08/20/69	----
SH-400	06/25/69	39.0	08/20/69	36.1
SH-300	06/25/69	33.8	08/20/69	41.4
SH-200	06/25/69	20.6	08/20/69	31.4
SH-100	06/25/69	28.2	08/20/69	40.8

attributed to dilution by runoff during June. Samples from Shaviovik River were usually higher than the Canning River samples from the same time interval.

Concentrations of magnesium were not as high as calcium and did follow the same pattern from time interval to time interval but not from river to river. Magnesium ranged from 3.2 to 6.1 mg/l in Canning River and 2.1 to 6.2 mg/l in Shaviovik River (Table 43). Samples were predictably less concentrated in June that August. Data from both of these systems were similar to data from Sagavanirktok River.

TABLE 43. MAGNESIUM IN THE CANNING AND SHAVIOVIK RIVERS

Station	Date	Magnesium mg/l	Date	Magnesium mg/l
CA-400	----	----	08/15/69	3.2
CA-300	06/24/69	5.1	08/15/69	6.1
CA-200	06/24/69	4.8	08/15/69	5.6
CA-100	06/24/69	4.2	08/20/69	----
SH-400	06/25/69	4.5	08/20/69	4.7
SH-300	06/25/69	4.5	08/20/69	3.9
SH-200	06/25/69	2.1	08/20/69	3.2
SH-100	06/25/69	4.0	06/20/69	6.2

Concentrations of iron were consistently at 0.1 mg/l during August in both rivers (Table 44) which is somewhat lower than iron concentrations in the Sagavanirktok River.

TABLE 44. IRON IN THE CANNING AND SHAVIOVIK RIVERS

Station	Date	Iron mg/l	Date	Iron mg/l
CA-400	----	----	08/15/69	0.1
CA-300	06/24/69	----	08/15/69	0.1
CA-200	06/24/69	----	08/15/69	0.1
CA-100	06/24/69	----	08/26/69	----
SH-400	06/25/69	----	08/20/69	0.1
SH-300	06/25/69	----	08/20/69	0.1
SH-200	06/25/69	----	08/20/69	0.1
SH-100	06/25/69	----	08/20/69	0.1

Concentrations of chloride from both rivers (Table 45) were similar to the values in Sagavanirktok River. High concentrations were often from stations located near the mouth of the respective river and thus susceptible to salt water intrusion.

TABLE 45. CHLORIDE IN THE CANNING AND SHAVIOVIK RIVERS

Station	Date	Chloride mg/l	Date	Chloride mg/l
CA-300	06/24/69	1.11	08/15/69	1.11
CA-200	06/24/69	0.30	08/15/69	1.11
CA-100	06/24/69	2.33	08/20/69	----
SH-400	06/25/69	0.30	08/20/69	0.91
SH-300	06/25/69	0.30	08/20/69	0.91
SH-200	06/25/69	0.30	08/20/69	0.91
SH-100	06/25/69	0.30	08/20/69	1.11

In the Canning River, specific conductance values ranged from 171 to 265 umhos/cm in June and from 240-250 umhos/cm in August (Table 46). In the Shaviovik system, conductivity ranged from 175 to 255 umhos/cm in June and 240-268 umhos/cm in August. At any station, specific values were often higher in August than in June but ranges were similar. For any specific time, both of these stream systems usually have higher specific conductance than the Sagavanirktok River.

TABLE 46. SPECIFIC CONDUCTANCE OF THE CANNING AND SHAVIOVIK RIVERS

Station	Date	Specific Conductance µmhos/cm	Date	Specific Conductance µmhos/cm
CA-400	----	---	08/15/69	240
CA-300	06/24/69	195	08/15/69	250
CA-200	06/24/69	171	08/15/69	242
CA-100	06/24/69	265	08/20/69	----
SH-400	06/25/69	175	08/20/69	268
SH-300	06/25/69	255	08/20/69	259
SH-200	06/25/69	229	08/20/69	240
SH-100	06/25/69	221	08/20/69	240

In the Canning River, total alkalinity was significantly less in June (60.9 - 85.2 mg/l), than in August (97.6-107 mg/l), and both were less than the respective ranges from the Shaviovik River, 108-133 mg/l, and 119-130 mg/l (Table 47). The Canning River data are similar to the Sagavanirktok River data, although the latter has a greater range. The total alkalinity from the Shaviovik River is the highest observed.

TABLE 47. TOTAL ALKALINITY OF THE CANNING AND SHAVIOVIK RIVERS

Station	Date	Total Alkalinity mg/l	Date	Total Alkalinity mg/l
CA-400	----	----	08/15/69	104
CA-300	06/24/69	85.2	08/15/69	97.6
CA-200	06/24/69	81.3	08/15/69	107
CA-100	06/24/69	60.9	08/20/69	----
SH-400	06/25/69	133	08/20/69	129
SH-300	06/25/69	122	08/20/69	130
SH-200	06/25/69	108	08/20/69	122
SH-100	06/25/69	113	08/20/69	119

Total hardness in the Canning River ranged from 66.0-80.0 mg/l in late June and 124-127 mg/l in mid-August. In the Shaviovik River concentrations ranged from 80.0-110 mg/l in June and 116-123 mg/l in August. Shaviovik River values were generally higher than Canning River which in turn were higher than Sagavanirktok River concentrations in both June and August (Table 48).

TABLE 48. TOTAL HARDNESS OF THE CANNING AND SHAVIOVIK RIVERS

Station	Date	Total Hardness mg/l	Date	Total Hardness mg/l
CA-400	----	----	08/15/69	124
CA-300	06/24/69	80.0	08/15/69	127
CA-200	06/24/69	66.0	08/15/69	126
CA-100	06/24/69	74.0	08/20/69	----
SH-400	06/25/69	92.0	08/20/69	123
SH-300	06/25/69	110.0	08/20/69	121
SH-200	06/25/69	92.0	08/20/69	118
SH-100	06/25/69	80.0	08/20/69	116

Ranges of pH in Canning River and the Shaviovik River conform well to the standard established in the Sagavanirktok River. The Canning River was near the low end of the range and the Shaviovik was only slightly higher (Table 49).

TABLE 49. pH OF THE CANNING AND SHAVIOVIK RIVERS

Station	Date	pH	Date	pH
CA-400	----	----	08/15/69	7.97
CA-300	06/24/69	7.86	08/15/69	7.79
CA-200	06/24/69	7.88	08/15/69	7.72
CA-100	06/24/69	7.55	08/20/69	----
SH-400	06/25/69	7.77	08/20/69	7.96
SH-300	06/25/69	7.70	08/20/69	8.01
SH-200	06/25/69	7.83	08/20/69	7.91
SH-100	06/25/69	7.77	08/20/69	8.02

Values of Total Organic Carbon (TOC) are listed in Table 50. In the Canning River, the TOC range is 5-10 mg/l. In the Shaviovik River the TOC range is 7-11 mg/l. These concentrations correlate well to Sagavanirktok River data from ice free intervals while data collected during April range much more widely (Table 50).

TABLE 50. TOTAL ORGANIC CARBON IN THE CANNING AND SHAVIOVIK RIVERS

Station	Date	TOC mg/l	Date	TOC mg/l
CA-400	----	----	08/15/69	9
CA-300	06/24/69	8	08/15/69	4
CA-200	06/24/69	9	08/15/69	8
CA-100	06/24/69	10	08/20/69	----
SH-400	06/25/69	7	08/20/69	8
SH-300	06/25/69	8	08/20/69	11
SH-200	06/25/69	9	08/20/69	10
SH-100	06/25/69	8	08/20/69	9

GALBRAITH AND NORA FED LAKES

General descriptions Galbraith and Nora Fed Lakes and the surrounding area have been presented in an earlier section. Chemical data for Galbraith and the Nora Fed Lakes are presented in Table 51.

TABLE 51. CHEMICAL DATA FOR GALBRAITH AND NORA FED LAKES

Parameter (units)	Galbraith Lake	Date	Nora Fed Lakes #1	Nora Fed Lakes #2	Date
Turbidity JTU	21	06/11/69	15	12	06/26/69
	17	06/26/69	9.8	5.2	08/22/69
	15	04/21/69			
Color (units)	29	06/11/69			
	3				
Fixed Suspended Solids (mg/l)	20	06/11/69			
	20	06/26/69	18	31	06/26/69
	14	08/21/69			
	14	08/21/69	11	8	08/22/69
Ammonia (mg/l)	0.04	06/11/69			
	0.04	08/21/69			
Nitrate (mg/l)	0.02	06/11/69			
	0.03	06/26/69			
	0.03	08/21/69			
	0.02	08/22/69			
Phosphate (mg/l)	0.52	06/11/69	0.016	0.06	06/26/69
	0.03	06/26/69			
	0.04	08/21/69			
	0.02	08/22/69	0.04	0.01	08/22/69
	0.20	04/21/70			
Silica (mg/l)	1.1	06/11/69			
	1.1	08/21/69			
Sodium (mg/l)	0.35	06/11/69			
	0.28	08/21/69			
Potassium (mg/l)	0.50	06/11/69			
	0.31	08/21/69			
Calcium (mg/l)	31.3	06/11/69			
	26.9	08/21/69			
Magnesium (mg/l)	3.7	06/11/69	2.0	1.2	06/26/69
	2.0	06/26/69			
	3.3	08/21/69			
	2.9	08/22/69	2.6	1.5	08/22/69
	5.0	04/20/70			

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TABLE 51 (continued)

Parameter (units)	Galbraith Lake	Date	Nora Fed Lakes #1	Nora Fed Lakes #2	Date
Iron (mg/l)	0.6	08/21/69		0.2	08/20/69
	0.3	08/22/69	0.3		08/22/69
Chloride (mg/l)	1.31	06/11/69			
	0.91	06/26/69	1.92	0.70	06/26/69
	1.01	08/21/69			
	1.21	08/22/69	3.93	1.81	08/22/69
	0.30	04/21/70			
Specific Conductance (μhmos/cm)	130	06/11/69			
	172	06/26/69	131	95	06/26/69
	158	08/21/69			
	152	08/22/69	222	158	08/22/69
	295	04/21/70			
Alkalinity (mg/l)	90.0	06/11/69			
	72.8	06/26/69	72.1	54.5	06/26/69
	80.1	08/21/69			
	118.7	04/21/70			
Total Hardness (mg/l)	88.0	06/11/69			
	76.0	06/26/69	50.0	41.0	06/26/69
	80.0	08/21/69			
	81.8	08/22/69	99.0	69.7	08/22/69
pH	8.22	06/01/69			
	7.81	06/26/69	7.65		06/26/69
	8.04	08/21/69		7.88	08/20/69
	7.82	08/22/69	7.86		08/22/69
	7.88	04/21/70			
Total Organic Carbon (mg/l)	8	06/11/69			
	8	06/26/69	9	10	06/26/69
	8	08/21/69			
	8	08/22/69	6	11	08/22/69
	7	04/21/70			

Concentrations of turbidity in Galbraith Lake exhibited a range of 15-21 JTU which is somewhat higher than the range of 5.2-15 JTU from Nora Fed Lakes. The higher concentration in Galbraith Lake is probably due to wave action on an exposed deposit of clay-type (probably bentonite) material on the northern shore.

Color ranged from 3 to 29 units in Galbraith Lake. While color is not particularly high, the higher concentration in June is probably due to runoff transporting dissolved material into the lake system.

Fixed suspended solids ranged from 14 to 20 mg/l in Galbraith Lake and from 8 to 31 mg/l in Nora Fed Lakes. In all lakes, the fixed suspended solids decreased from June to mid August.

Concentrations of nutrients are generally low. As expected, ammonia and nitrate concentrations were low. In Galbraith, ammonia was consistently 0.04 mg/l and nitrate varied slightly, 0.02-0.03 mg/l. Total phosphate concentrations ranged from 0.02-0.52 mg/l in Galbraith Lake and from 0.01-0.06 mg/l in Nora Fed Lakes. Silica concentrations were 1.1 mg/l.

Cation concentrations in Galbraith Lake were about as expected.

Sodium and potassium ranged from 0.28-0.35 mg/l and 0.31-0.50 mg/l respectively with the lowest concentrations occurring in August. Calcium concentrations were higher in June (31.3 mg/l) than in August (26.9 mg/l) and were the most concentrated component of the cations. Magnesium ranged from 2.0 to 5.0 mg/l. During ice-free intervals, concentrations remained about the same but a ranged from 2.0 to 5.0 mg/l. During ice-free intervals, concentrations remained about the same but a significant increase was observed in April when 5.0 mg/l was recorded. Concentrations in Nora Fed Lakes were less or at the lower limit of Galbraith Lake samples. Iron was found in relatively low concentrations; 0.3-0.6 mg/l in Galbraith Lake and 0.2-0.3 mg/l in Nora Fed Lakes. These iron data were collected in August.

Concentrations of chloride in these lakes were surprisingly high in some cases. In rivers, many high concentrations could be related to the influence of the Beaufort Sea. However, these lakes are too far inland to be affected by the Beaufort Sea in all but unusual storm conditions. Concentrations of chloride were consistently higher in Nora Fed #1 than in Nora Fed #2. Both were highest in August: Nora Fed #1 contained 1.92 mg/l in June and 3.93 mg/l in August while Nora Fed #2 contained 0.70 mg/l in June and 1.81 mg/l in August. In Galbraith Lake chloride concentrations ranged from 0.30 mg/l during April to 1.21 mg/l in August and 1.31 mg/l in early June.

Specific conductance, alkalinity, total hardness and pH are measurements of specific characteristics of dissolved and suspended components of water. These parameters are close to the ranges established in the river drainages. Specific conductance ranged from 130 to 295 umhos/cm in Galbraith Lake, from 131 to 222 umhos/cm in Nora Fed #1, and 95-158 umhos/cm in Nora Fed #2. In all three lakes, measurements taken in August were usually higher than those in June. The highest value was generated from a sample collected in April. Concentrations of alkalinity ranged from 72.8 to 118.7 mg/l in Galbraith and from 54.5 to 72.1 mg/l in Nora Fed Lakes (Table 51). Again, the highest concentration was found in April. Total hardness ranged from 76.0-88.0 mg/l in Galbraith Lake and 41.0-99.0 mg/l in Nora Fed Lakes. Concentrations were generally higher in August with the highest concentration found in Nora Fed No. 1. Still higher values would probably have been found if samples had been collected in April. pH was consistently on the alkaline side of neutral. Galbraith pH ranged from 7.81 to 8.22 while in Nora Fed Lakes. pH ranged from 7.65-7.88. These latter lakes are probably less alkaline because of the presence of more organic material and subsequent products of decomposition.

Total organic carbon concentrations ranged from 6 to 11 mg/l in Nora Fed Lakes and from 7 to 8 in Galbraith.

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